
Albert
1919

YEAR BOOK

OF THE

American Iron and Steel Institute

1919

MAY MEETING - - - - - - - NEW YORK
OCTOBER MEETING - - - - NEW YORK

Published by the
AMERICAN IRON AND STEEL INSTITUTE
61 Broadway, New York

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FOREWORD

This is the ninth Year Book of the American Iron and Steel Institute.

The first Year Book gave the proceedings of the International meeting which began in New York on Friday, October 14, 1910, and was continued in Buffalo, Chicago, Pittsburgh and Washington.

In 1911 the Institute held no general meetings.

The second Year Book gave the proceedings of the two general meetings held in 1912, the May meeting in New York and the October meeting in Pittsburgh.

The third Year Book gave the proceedings of the two general meetings held in 1913, the May meeting in New York and the October meeting in Chicago.

The fourth Year Book gave the proceedings of the two general meetings held in 1914, the May meeting in New York and the October meeting in Birmingham.

The fifth Year Book gave the proceedings of the two general meetings held in 1915, the May meeting in New York and the October meeting in Cleveland.

The sixth Year Book gave the proceedings of the two general meetings held in 1916, the May meeting in New York and the October meeting in St. Louis.

The seventh Year Book gave the proceedings of the two general meetings held in 1917, the May meeting in New York and the October meeting in Cincinnati.

The eighth Year Book gave the proceedings of the general meeting held in May, 1918, in New York. On account of the war no October meeting was held.

The present volume contains the proceedings of the two general meetings held in 1919, the May meeting in New York and the October meeting in New York.

James T. McCleary,
Secretary.

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CHARLES M. SCHWAB .... Vice-President
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AMERICAN IRON AND STEEL INSTITUTE

FIFTEENTH GENERAL MEETING

New York, May 23, 1919.

The Fifteenth General Meeting of the American Iron and Steel Institute was held at the Hotel Pennsylvania, New York City, on Friday, May 23, 1919.

Following the usual custom, three sessions were held. The forenoon and afternoon sessions were devoted entirely to the reading and discussion of papers. The evening session, which was held in the Grand Ballroom, included the annual dinner. The papers and discussions were concerned chiefly with problems of metallurgy and of business. As this was the first general meeting of the Institute since the signing of the armistice, the addresses at the evening session were largely devoted to topics relating to the war.

During the meetings the Secretary had a temporary office, near the room in which the meetings were held, for the convenience of members, general information and the distribution of programs and identification buttons.

Following the forenoon session the members of the Institute were its guests at a buffet luncheon which was served in the Grand Ballroom. During this recess, also, the Directors held a Board meeting.

The attendance was so large that it overtaxed the accommodations of the hotel. The room in which the day sessions was held was overcrowded, and the banquet in the evening not only filled the Grand Ballroom and its galleries but overflowed into the adjoining rooms.

On the following page will be found the program of the meeting. Judge Gary, President of the Institute, presided at the morning session. Mr. Charles M. Schwab and Mr. John A. Topping, Vice-Presidents, presided during the afternoon session. Judge Gary acted as toastmaster at the evening session.

PROGRAM—MAY MEETING

FORENOON SESSION, 10:00 A. M.

Address of the President.............................ELBERT H. GARY
Chairman, United States Steel Corporation, New York

The Work of the National Bureau of Standards as Related to Industrial Problems..............SAMUEL W. STRATTON
Director, Bureau of Standards, Washington, D. C.

Electrically Heated Soaking Pits, Reheating and Annealing Furnaces, and Automatic Furnaces for Heat Treatment as applied to the Steel Industry.THADDEUS F. BAILY
President, The Electric Furnace Co., Alliance, Ohio

Discussion..J. W. RICHARDS
Professor of Metallurgy, Lehigh University, Bethlehem, Pa.

Discussion..W. G. KRANZ
Vice-President, The National Malleable Castings Co., Cleveland, Ohio

The American Bridge Company's Forge Plant at Gary, Indiana..C. J. WALKER
Assistant Superintendent, American Bridge Co., Gary, Ind.

AFTERNOON SESSION, 2:00 P. M.

Present Knowledge Concerning Non-Metallic Impurities of Steel (Sonims)..........................HENRY D. HIBBARD
Consulting Engineer, Plainfield, N. J.

Discussion..JOHN A. MATHEWS
President, Halcomb Steel Co., Syracuse, N. Y.

Discussion..G. L. KELLEY
Engineer of Tests, Midvale Steel & Ordnance Co., Nicetown, Pa.

Discussion..L. B. LINDEMUTH
Consulting Engineer, 40 Wall St., New York

Discussion..FRANK B. POTO
Chief Chemist and Metallurgist, Otis Steel Co., Cleveland, Ohio

The By-Product Coke Plant at Clairton, Pennsylvania.FRANK F. MARQUARD
Superintendent, By-Products Coke Plant, Clairton, Pa.

Standardization of Ship Materials..................FRED T. LLEWELLYN
Federal Shipbuilding Co., Kearny, N. J., and Chickasaw Shipbuilding Co.. Mobile, Ala.

Methods of Charging Raw Materials into the Blast Furnace.JACOB A. MOHR
Superintendent, Carrie Furnaces, Carnegie Steel Co., Rankin, Pa.

Discussion..R. W. H. ATCHERSON
Blast Furnace Superintendent, Inland Steel Co., Indiana Harbor, Ind.

Discussion..HARRY S. BRAMAN
Superintendent, Blast Furnace and Steel Department, Youngstown Sheet & Tube Company, Youngstown, Ohio

Discussion..R. V. MCKAY
Superintendent, Blast Furnaces, Bethlehem Steel Co., Steelton, Pa.

EVENING SESSION, 7:00 P. M.

American Steel in the World War................JOSEPH G. BUTLER, JR.
Vice-President, Brier Hill Steel Co., Youngstown, Ohio

Impromptu Remarks in Response to the Call of the President.

ADDRESS OF THE PRESIDENT

Elbert H. Gary

Chairman, United States Steel Corporation, New York.

I am glad there are so many here this morning, though I am very sorry the room is not larger. There is a bigger room in the hotel, which will be occupied this evening, and then there will be considerable over-flow.

This is an inspiring sight. Those of you who have lately joined the Institute can imagine the feelings of those who were members at the beginning, and who started out with the fear that there might be failure of great success. You can understand how appreciative we are, how proud of the Institute, and how grateful we are for the magnificent support which has been given by you.

It is a source of some discomfort that some of us who are older cannot call every man by his name and remember him as well as we ought. I think it is only fair to suggest that whenever any of you recognizes another, even though the other does not seem to know you, you should go up to him, take him by the hand and call him by name, and tell him your name. And then again, there are large numbers whom we know perfectly well, whose countenances are familiar, but whose names we cannot instantly recall. Remember, we are the ones who are embarrassed, and that there is no disposition on the part of any one of our officers or older members to ignore or minimize the importance of every single man who comes to these meetings.

We are very proud of our association and of the Institute. We are proud of the great success which has resulted, of the work which has been done by the individual members, by the various committees and by the Institute itself throughout the war.

I trust that every member of this Institute recognizes

the fact that he is just as important a member as any other, that we meet here upon the level and we part upon the square.

A great change has come over the people of all nations since our last annual meeting. The world war seems to have been terminated though the details of the peace terms have not yet been fully agreed upon. We may properly rejoice that negotiations have reached the point where it seems probable peace will be established, although we cannot as yet see clearly into the far future. Glancing back one year we may be thankful. The outlook in France and other parts of Europe was then very dark. We were anxious and distressed, but not without the courage of conviction as to final results. Right has triumphed. An overruling Providence has protected civilization against ruthless attack. All nations and peoples rendering service on the side of justice, faithfully and effectively performed their respective parts.

It is appropriate to refer briefly to the part the members of this Institute performed in winning the war; not with a disposition to boast or to claim credit, but rather with a feeling of gratitude that they were permitted to assist in defending a righteous cause.

During the progress of the war we were frequently informed by representatives of the United States Government, military and civil, who were in authority and directly connected with the purchase of supplies required for war purposes, that steel was of the highest importance and we were urged to increase capacity and to hasten production; we were requested to devote our time, money and energy in behalf of our Government and its associates in the war to the exclusion of everything else. It was emphasized that if disaster was to be averted there must be additional war material, food supplies and transportation facilities, and that larger and larger quantities of steel were fundamental to all these means of carrying on the war. Repeatedly statements were made to us that

the demands for steel, both as to quantities and deliveries were impossible of fulfillment.

However, the manufacturers never became disheartened or demoralized. They listened patiently to the claims and reasons presented and then considered carefully all figures bearing upon the subject of necessities and ability to produce and made their calculations accordingly. Fired with feelings of patriotism, yet with composed minds and determined spirits, those in control of the iron and steel industry again and again promised that steel would be furnished when and as required for military purposes.

It is sufficient to say that in every substantial particular the iron and steel industry made good all promises. There were no deficiencies in quantities nor delays in deliveries which were harmful. If these matters had been left entirely in the hands of the General Committee of the American Iron and Steel Institute there would have been no delinquencies whatever.

Apropos to our efforts it is pertinent to quote from verses by Miss Dorothea A. Verrett:

"A war of steel has just been finished,
Steel of helmet, gun and shell,
Steel of 'first-aid', steel of surgeon,
Steel of signal bar and bell,

Steel of bridges, buildings, steamships,
Steel of cars and frames and rails,
Steel of tanks and pipes and ovens,
Steel of pots and bolts and nails,

Steel of needles, anchors, axes,
Steel of knives and saws and spires,
Steel in work of engineering,
Steel of hammers, rods and wires,

Steel of plowshares, steel of harrow,
Steel to till the fields of war,
Steel of tools and steel of engines,—
Steel in peace for evermore."

I am not sufficiently familiar with the facts to detail what personal sacrifices have been made during the war by members of this Institute. Many of its members entered the war as privates or officers and offered their lives for their country. Sons and relatives of others joined the service and numbers of them cheerfully marched into the very teeth of destructive implements of war. Many were killed and others wounded. Some day it is to be hoped a careful record will be made for preservation in our archives. We pause now only to say: We deeply sympathize with our friends and associates whose sons or other relatives have died or been wounded in the war. For those who made the supreme sacrifice we cherish in our hearts a feeling of sadness and sorrow. For all who entered the military service we entertain sentiments of gratitude for their devotion to country, their defense of civilization and their protection of our liberty and freedom. They have made a glorious record and this Institute is proud to have been associated with them directly or through relationship.

We may hope that our contact with the war, far behind but in steadfast support of the battle lines, has been of real benefit to us in our characters and dispositions; that our patriotic instincts have been broadened and sharpened; that our vision has been extended and illumined. We have been made to more fully realize our duty and responsibility in reference to the Government, to each other and to all others who are connected with or interested in our affairs. We have been reminded in one way or another that we are selfish and sometimes greedy; that we are often narrow and unreasonable; that we are inclined to resent unfavorable criticism even though it is deserved. And we have learned to better appreciate the merits of others with whom we have been brought into discussion and decision concerning the matters which affected our pecuniary interests. We have been convinced that Governmental representatives who disagreed with us were right and that we were wrong; that because we

were financially interested and they disinterested they had the advantage in debate and judgment. We must give credit to them for unbiased and intelligent consideration of our affairs. We should remember and profit by our experience in Washington during the last eighteen months of the war. We always intended to be fair and reasonable, but were sometimes mistaken. Invariably the arguments against our contentions were presented intelligently, courteously and frankly.

We now have reason to assume the peace terms will be agreed to and subscribed at least by the majority of Governments and that a League of Nations for the continued preservation of peace will be established. A large majority of the people of all countries are favorable to these results and their desire and will must prevail. If the plan adopted, in form or substance, shall prove, by experience, to be imperfect or incomplete, corrections or amendments can be made later. If the plan turns out to be unworkable or unsatisfactory it can and will be abandoned. Naturally every one is wondering whether or not peace will be permanent or long continued. There are numerous things to be considered, too many for discussion or even reference at this time; but the controlling factor in this respect is one of fairness to all nations, taking all the facts and circumstances into account. If, at the start, either the treaty of peace or constitution of the League of Nations is manifestly unjust and unfair to any leading country it will turn out to be a temporary arrangement only. Honesty, justice, truth and christian spirit are all kindred to and have a bearing upon the idea of fairness.

It is to be presumed the Central Governments with their associates in the war will sign the terms of peace offered, or will at least submit to them. They are helpless and have no alternative. For this reason, if for no other, those who tender the terms of peace should be more considerate and painstaking.

At this particular time it is difficult for anyone con-

nected with our side of the military conflict which has been raging to view the situation dispassionately. The precipitation of the war by the German leaders seems to us to have been unjustified and unconscionable; their conduct, brutal and remorseless; their treatment of captives and captured territory, cruel and diabolical; their disregard of law and right and human sanctity, barbarous and dastardly. This has outraged our feelings and inflamed our passions. It could not be otherwise. If we are thus affected, what must be the mental attitude of those who were in close proximity to the scenes of horror.

Nevertheless there must be maintained at present composure and judicial temperament having in view the long future and the vital welfare of the whole world. As we hate wrong, it is natural to hate those who perpetrate wrong, and we often entertain these sentiments without discrimination of persons. The leaders of the German people, in control of affairs, civil and military, should be distinguished from the masses, who are responsible for the conduct of the former but not equally guilty of moral turpitude. Therefore the penalties imposed should be different. Having some bearing upon the subject, I refer to a speech delivered by John J. Crittenden, an eminent lawyer and statesman, which I read in my younger days. He indulged in the use of an allegory, the substance or idea of which I will give you.

At the time of the creation God called into conference his three Angels, Justice, Truth and Mercy, and inquired whether He should create man. Justice answered: "Nay, he will disregard and trample upon Thy laws." Truth replied: "Nay, he will violate Thy commandments and pollute Thy sanctuaries." But Mercy exclaimed: "Yea, Lord, I will guard and guide him." And God created man and said unto him: "Thou art the child of Mercy, deal mercifully with thy brethren."

Those directly connected with the cruel and criminal offenses against humanity during the war should personally receive adequate, even capital, punishment if and

when deemed necessary, not in a spirit of vindictiveness or revenge, but as an example to deter others from the perpetration of crime which is recognized by civilized peoples to be the purpose of personal penalties. The citizens generally of an offending and conquered country, to the extent of their ability, should make full reparation and restitution for all the damage that has been inflicted, except and unless the same is waived in whole or in part. But as to punishment of the people at large of any country, which might result in unnecessary personal and physical cruelty and suffering, notwithstanding all are responsible for the acts of their official representatives, it seems to me the conquerors should be merciful.

The truth ought to be ascertained and published; justice should be administered in vindication of law and for reparation to the innocent who have suffered; but it should be tempered with mercy, depending upon circumstances.

Applying these suggestions to the international settlements which are to be concluded, care should be exercised in determining geographical boundaries, in limiting productive facilities and capacity, opportunities for development, means for progress and prosperity, the protection against unwarranted attack, racial equality and fraternity, the future preservation, comfort, liberty and general welfare of all the people of all the countries. Friends of today may be enemies hereafter and *vice versa.* An unfair, unrighteous settlement will not long continue in force. Personally, I do not sympathize with the claims made or reasons given by the German leaders for their acts nor condone their offenses, but I would favor a decision that is fair, wise and christianlike.

The question of leaving to Germany the facilities and opportunity for production and financial success in order to enable her to pay the large sums which she will be found to owe need not be discussed at this time. The saving from starvation of innocent people in Germany is of higher importance.

Many of us remember with sadness our conferences with German and Austrian steel masters at Brussels. They were agreeable and satisfactory. It is within the bounds of possibility that representatives from all the steel producing countries of the world may hereafter, perhaps sooner than we now expect, meet to consider how best to advance the interests of all. We have never had business differences with any of them which would prevent our welcoming such a meeting. We would be fair, frank and honorable and, of course, would expect and exact reciprocal treatment.

Believing the war is ended and that peace will soon be declared, we instinctively turn our thoughts to the present and future economic situation. We realize that competition between the business men of this country and those of other countries, and between ourselves, however good-natured and friendly, will be persistent and aggressive. So far as the members of this Institute are concerned it will never intentionally be wanton and destructive. We have learned the folly and the wrong of such a course. But we believe that the underlying reason for precipitating the late war was economic and that the question which is uppermost in the minds of many, if not most of the representatives at the Peace Conference, is economic, and that a desire for economic advantage and success will actuate the political, financial and industrial administrators of affairs of all countries in future decisions and efforts. We have established friendships with our neighbors across the seas which are genuine and lasting. This will result in benefit to them and likewise to us. But we should not be deluded into the conclusion that any of them will neglect an opportunity to extend influence or to secure trade, or to profit, even at our expense, so far as the same can be accomplished by legitimate means. This is their right and we cannot reasonably object. However, so far as it is proper, we must be prepared to meet the competition that is sure to appear and we must be diligent, alert and vigorous.

As between ourselves, we believe thoroughly in competition; but also in co-operation as often expressed. We believed in this before, during and after the war. It is a principle that will not yield to destructive forces, although it is sometimes selfishly forgotten.

We must, right at this time, consider of first importance our own attitude and conduct with respect to the business affairs under our charge. We have not always been exactly right in some, and perhaps many, particulars, though I think we may properly claim that our intentions were good. Our attitude toward each other, toward our customers, our stockholders, our employees, the general public, or the administrators of public affairs at times may have deserved complaint.

Whatever may be the facts relating to the past, let us this very day resolve anew that for the future we, who represent large interests and are recognized as important factors in industrial life, will demonstrate that our aim is to treat thoughtfully and fairly every interest, private or public, that comes within range of our responsibilities or influence. This is not said in a spirit of repentance or accusation. No past act or omission is in mind. Our intentions have been above reproach. It is attempted only to emphasize the fact that every one of us should constantly strive to convince others that our business will be so managed as to be of substantial benefit to all concerned. I think the sentiment of the general public toward corporations or concentrated capital has been growing decidedly better during the last decade or more. Perhaps there is reason for this. Possibly the management of capital has improved. At any rate let us do what we can to prove the commendations, which have been published in the public press or periodicals or spoken from the platforms or stated by public officials whom we have attempted to serve, were justified; that we appreciate them and will continue to deserve them.

And then, if we do our part in supporting the things that are right and of both public and private importance,

may we not expect to reap an indirect advantage? There are things to be done by the legislative and administrative departments of Government which are necessary to the protection of the industries of this country, and this involves the very life, the prosperity and progress and comfort of all the people. As other countries will do everything practicable to advance their interests, so we should do likewise. All our industrial lines should be placed and maintained on a parity with other successful countries. To the extent that private enterprise receives protection, assistance, and advantage by the laws or rules of other countries, the same should be afforded by our laws and rules, so as to place us on a parity of cost in production and transportation. It is time that industry and enterprise in the United States shall be encouraged and protected instead of being attacked, interrupted or destroyed. Our nation, now the leader, financially, commercially and industrially, may be continued in this position or compelled to occupy a lower place, depending upon the attitude of our own people in official or private life, or both. We will do our part.

These questions relate to material strength and growth and have no relation to partisan politics. The large majority of our citizens are insisting upon business progress and prosperity so far and so long as the same can proceed and be maintained within the limits of safety to the public welfare. Beyond that no reasonable person desires to go. Our productive capacity is large and increasing. If given a fair opportunity to compete with other countries by the utilization of our natural resources our producers will retain a satisfactory position in the race for success. When we consider the preparation other nations are making to advance their pecuniary interests in every part of the world we must conclude that to maintain the position which we are entitled to hold we must be unfettered by unreasonable or unnecessary restrictions. If business, big or small, shall deserve to succeed, it will be permitted. As to exactly what laws or modifications or

application of laws are necessary I may express opinions at another date or place, though I believe others more competent and occupying high official positions have already reached wise conclusions and will act accordingly.

Since the armistice was signed the steel industry has made two substantial reductions in selling prices, first by voluntary action, December 9th, and then March 21st, after consultation and discussion with the members of the Industrial Board of the Department of Commerce. There are incidents connected with the efforts of the Secretary of Commerce to stabilize conditions which interfered more or less with business activity. You are familiar with the subject. At present there is a perceptible and gradual improvement. It seems probable this will continue and increase. On the whole, our business during the last six months has been better than we had reason to expect. After what has occurred during the last few years it is wonderful that conditions are so good. As I have said before, more than once, there is a large and fairly profitable business ahead. The necessities of the purchasing public are piling up. Some may wait too long before placing the orders under contemplation. As you are aware, the wheat crop of the season is enormous—far above previous calculations—and it will soon be harvested, threshed, transported and converted into cash. This will provide business and money for the carriers. What they will do with it I cannot say, but they probably will make some necessary improvements in roadbed and equipment. Other crops will soon be coming on; from present appearances the production this year will exceed all former records. The price of copper is increasing; and it is expected to be selling in the near future at twenty cents. Most, if not all, of us are making expenditures in preparation for the future business that is coming. Go into the large new hotels and witness the crowds. Secure a room, if it is possible, and then make inquiries of travelers from the far West, Southwest, and South, and you will hear good reports. They have confi-

dence in the future and are acting accordingly. Look for a pessimist. You will find he is a rarity. Enter a jewelry store, or retail stores generally, and you will be surprised by the number of purchasers. Gaze upon the throngs of people on the city streets and the double rows of automobiles going in either direction. Visit the country and be astonished by the number of motor cars. Inquire for a house in New York which is for rent or sale and see for yourself that they are scarce and that prices are advancing. It is remarkable how many evidences of business activity there are. Gentlemen, the people of this country are rich and growing richer. It is estimated the wealth of this country is equal to one-third or more of the total wealth of all countries; that there is held by the banks fifteen or sixteen billion dollars; that the money in circulation is about fifty-six dollars per capita, as against about thirty-four dollars before the war. What is it to be supposed will be done with it? Why, invested and expended in order to increase wealth. Perhaps you and I will get some of it, and if so we will spend or invest it for we are like other human beings. There is still room in this country for the optimist, but little space for the pessimist. If the tax assessor and collector will only permit us to retain a little fairer percentage of our earnings we shall be happy; and we are beginning to see a gleam of light on this subject.

Patience and confidence are justified, and, with these, prosperity is assured. (Continued applause.)

President Gary: There will be now afforded informal discussion under the five minute rule of the Chairman's remarks. You can make it formal or informal or—infernal, without hurting my feelings. (Laughter.) If it is desired to speak at this time I will be very glad to give anyone the opportunity. If not, we shall now have the pleasure of listening to a paper by Mr. S. W. Stratton, Director, Washington, D. C., on The Work of the Bureau of Standards as related to Industrial Problems. Mr. Stratton. (Applause.)

THE WORK OF THE NATIONAL BUREAU OF STANDARDS AS RELATED TO INDUSTRIAL PROBLEMS

Samuel W. Stratton
Director, Bureau of Standards, Washington, D. C.

I consider it a very great pleasure to meet with you this morning and present very briefly the work of the Bureau of Standards, which ought to be a great deal more useful to you than it is. I was greatly pleased with the remarks of your Chairman as to the relation of your industry with the Government during the war, and I want to say that on the part of the Government there is a decided tendency toward improvement along the direction of basing their decisions, especially in regard to materials purchased, upon the facts of the case and to do away with the old plan of hiding ignorance behind authority. It is about this principle of basing purchases upon merit that the work of the Bureau of Standards has grown up. Its very name signifies a standard. Unfortunately the term "standards" has been interpreted in the past to mean measurements of length, capacity and similar things, but the term "standards" has come to mean a great deal more than this. There are the physical constants you use every day, many of which were determined long ago by methods which were not precise, and which must be redetermined. This relates to the properties of materials very largely. Then again, there is the field of standards of quality, and it is in connection with these standards that much of the work of the Bureau has been developed. The Bureau serves as an advisory laboratory to the various branches of the government, and the need for satisfactory standards of quality has been brought to our attention to a great extent in this manner, particularly during the war.

The field of standards of measurement includes electrical standards, temperature standards, standards of light, and so on. To prepare these standards, and, what is more important, to provide the best methods for their use, involves the most difficult problems in physics and chemistry, and necessitates the use of laboratories equipped with the most refined apparatus.

It is just as necessary for us to have standards of quality that are precise, and which can be used in relation to materials, as it is for us to have correct yardsticks or bushel measures. It is a great mistake to assume that in building up standards of quality the Bureau acts in an arbitrary manner; it serves only as the medium between the manufacturer and the purchaser. Questions pertaining to the quality of materials are always arising with the purchaser and with the manufacturer. No one is more interested in the properties of materials or the conditions upon which their quality depends than the manufacturer, hence a very close working relation has grown up between the industries and the Bureau.

Whenever it is necessary to investigate a material, whether the request comes to us through a government department or from an industry, both parties are called in and the Bureau serves as the intermediary and the adviser in scientific matters. The standard produced is the result of the best experience of both the user, who is supposed to know how to state what he wants, and the manufacturer, who is supposed to state what he can do, and if we proceed along those lines we will eradicate most of the difficulty that is arising in connection with Government purchases. But, while the placing of Government purchases upon a proper basis is important, it is insignificant as compared with the value of the knowledge which we have been able to furnish the public as a result of this work.

No problems receive greater attention at the Bureau than those in connection with the metallurgical materials. The Division of Metallurgy is one of our largest depart-

ments. During the war we were given funds with which to build two large emergency laboratories, which are of permanent and suitable construction, and which will now be turned into laboratories devoted to what is called industrial research. One of them has been assigned almost entirely to metallurgical problems. I have prepared a statement of the various investigations in progress and contemplated, but the time is too short to read them. What I wish to bring before you, however, is the fact that if this work is to be a success, and if it is to be useful to you, it can come about only through your close co-operation.

The problems in which the Government should take an active part in solving are those of a fundamental nature, involving broad problems of physics and chemistry, and which form the foundation of an industry.

I wish I had the time to give you a list of the problems going on in the Division of Metallurgy in regard to both ferrous and non-ferrous metals. However, I am going to show a few slides, not only of the metallurgical equipment, but the work of the other departments of the Bureau as well. It is a great mistake to assume that all government activities are regulatory. The Bureau of Standards has not a single function of that kind. It is entirely helpful, intended to be fraternal rather than paternal, and to that end we invite your co-operation.

I would suggest that the American Iron and Steel Institute appoint a research committee, or a committee of its technical men, to visit the Bureau as often as they like, and work hand in hand with us, and see to it that we take up the problems that are of interest to the steel industry.

Many of the lantern slides to be shown refer to other lines of work, as has already been mentioned, but you will be interested in some of them, particularly those touching upon war work.

Few people realize the amount of work required in making standards useful to the public. They must have

Figure 1—Set of Weights

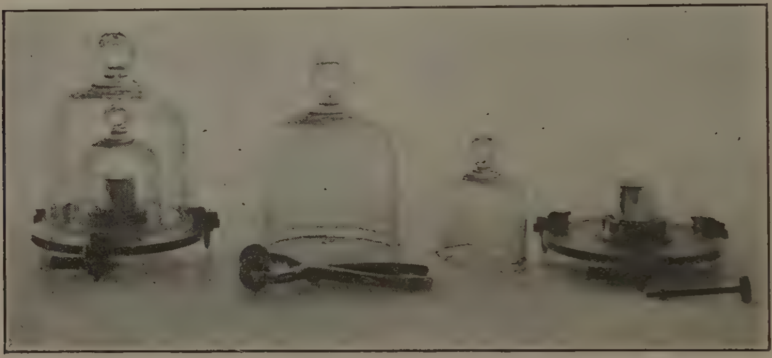


Figure 2—Two Standard Platinum-iridium Kilograms

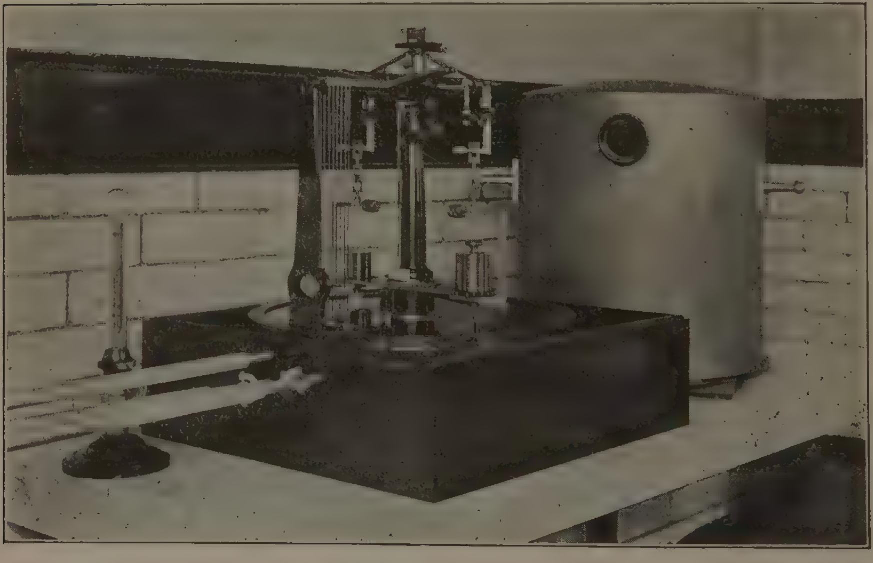


Figure 3—Vacuum Balance

a set of weights, such as that shown in Figure 1, and the building up of such a set is one of the most difficult problems which the Bureau has to meet. We make the unit from the standard which is preserved in a vault at the Bureau of Standards; this involves perhaps the most precise measurements that are made. The weights shown are made of a homogeneous alloy, a little light, coated with gold, and then polished down to the correct weight. The determination of the relation between the unit and the standard platinum-iridium weights shown in Figure 2, that we use for the prototype in this country, is an exceedingly difficult question. When we have one copy of it, the two are put on one side of a balance, and we produce a two; and then we must make another two or a one, until we get a five or a ten, going down the scale. This has its counterpart in every kind of measurement. You might just as well think of doing business without a set of coins or bills as to do it without a proper set of weights.

Figure 3 shows the precision appliance with which these weights are copied. It is shown here to illustrate the fact that in every one of these cases the instrument with which the standard is used is quite important. This balance is placed in a constant temperature vault, and is operated entirely from the outside by rods. The case is placed over it and the air exhausted to a certain extent, so that we are working under constant conditions of temperature and pressure. It takes weeks to make the comparison between the unit and the standard which you see on the left side. This has its counterpart in temperature and every line of measurement.

In Figure 4 is shown a test car fitted with weights of 10,000 pounds each. This car is sent about the country to test railroad track scales, and, what is more important, it is the standard by which is calibrated the test cars of the railroad companies. Sometimes as many as 50 per cent. of the large scales are found incorrect, due simply to the fact that no facilities have been provided for testing them.

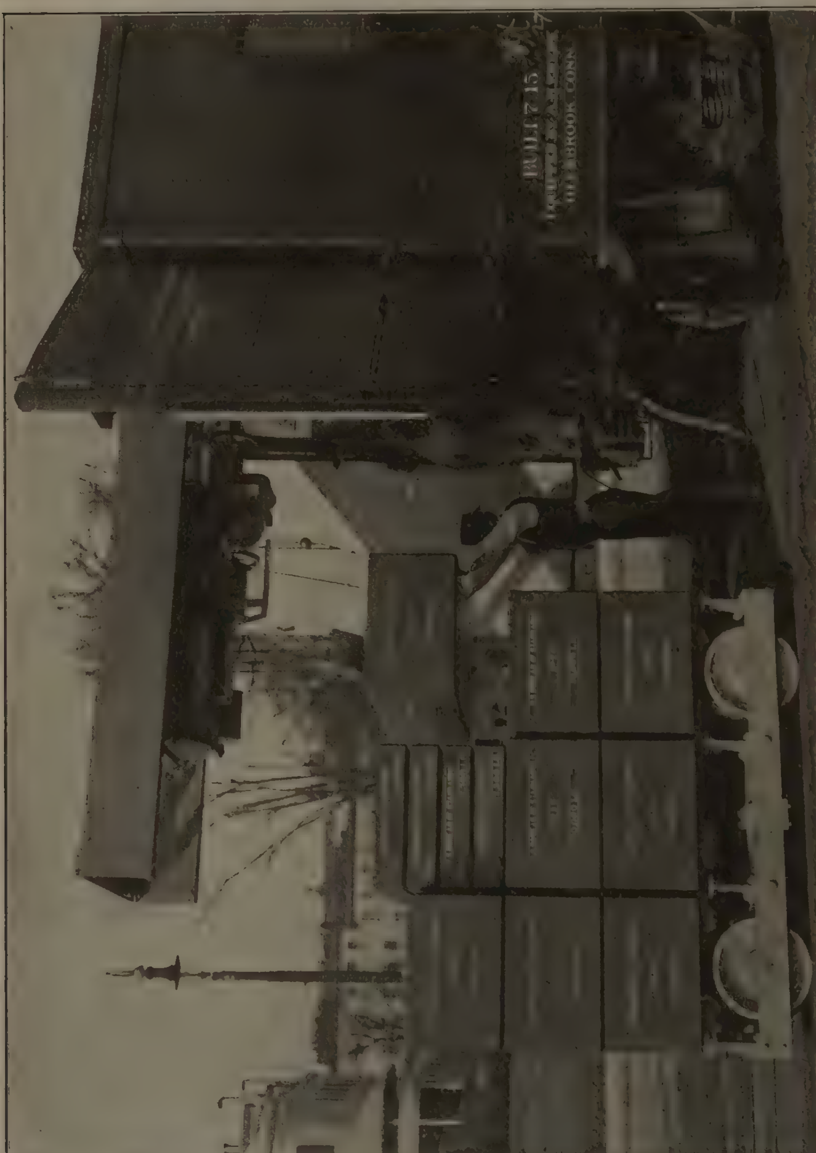


Figure 4—Railroad Track Scale Testing Car

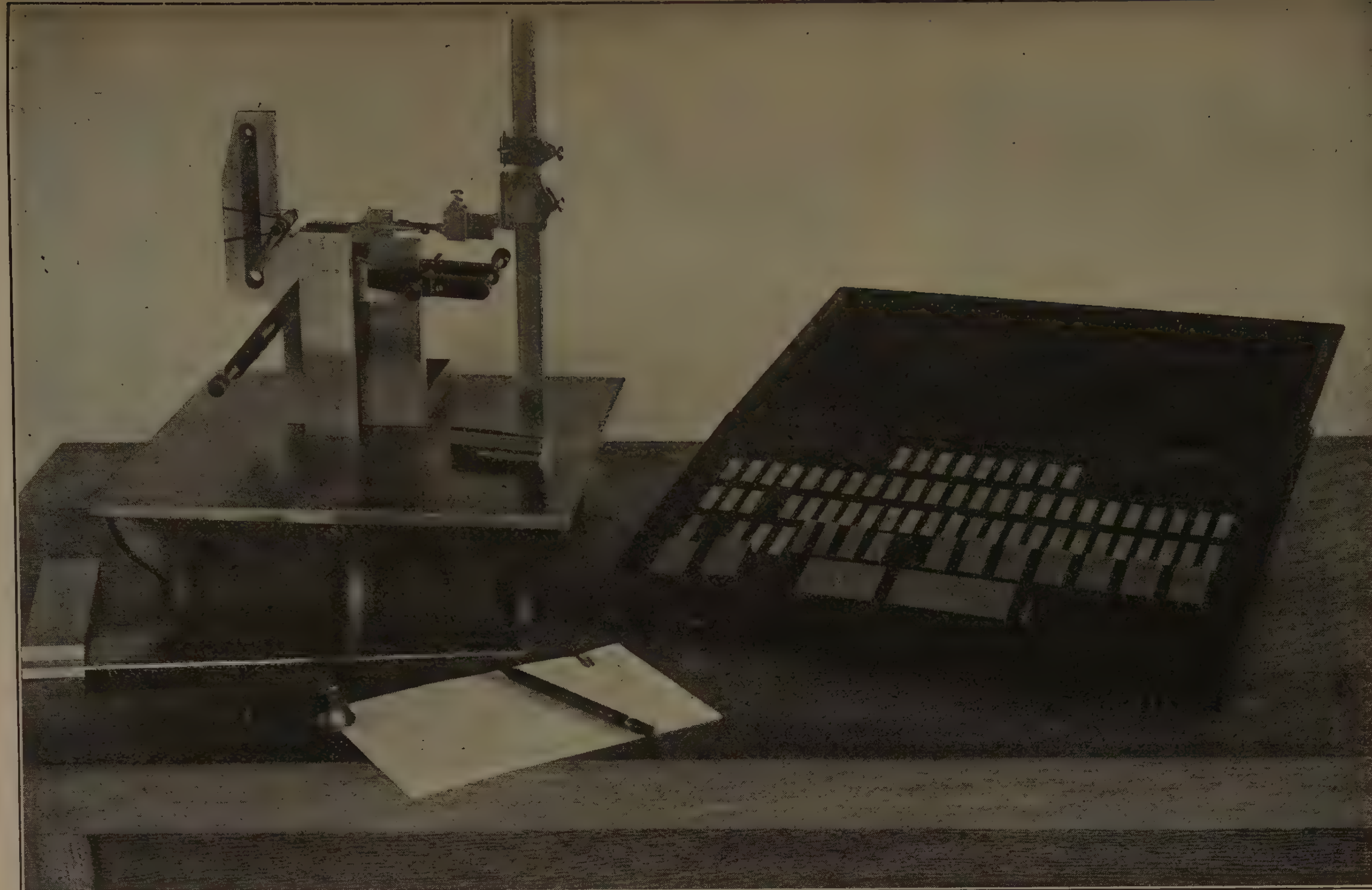


Figure 5—Standard Block Gages

Figure 5 illustrates a very interesting application to the standard of length. It is of no use to have only a standard of length filed in the vault where we cannot use it. During the war the question of building munitions upon the interchangeable plan was necessary. The earlier countries in the war suffered great inconvenience because they did not understand the importance of this question to begin with. Munition manufacturers test their gages by means of standard blocks similar to those shown here. Before the war they were all imported from Sweden. The early standards of length were end standards, but they were abandoned because they were not accurate enough for scientific work, and a line standard was prepared.

The standard meter of the archives in Paris, a replica of which is shown in Figure 6, is a platinum-iridium bar with two lines on it, but the manufacturer needs an end standard for his use. A Swedish manufacturer developed a method of manufacturing these end standards. The ends must be perfectly plane and parallel, and this is exceedingly difficult to accomplish. The method of manufacture has always been kept a secret. When we entered the war we were dependent entirely upon the foreign supply of these standards. However, a method was developed in this country for making them, and. what is more important, they are so accurate that the use of the line standard may be abandoned altogether as a primary standard.

A few years ago scientists measured the relation between the standard of length and certain light waves. Now the method of measuring by light waves has been found the most applicable to the measurement of these end standards, so they were not only made at the Bureau, but their manufacture was made possible because of this method of measuring by light waves. It is very interesting to note that this theoretical standard, which had been proposed so long by physicists, was first used in the manufacture of munitions.

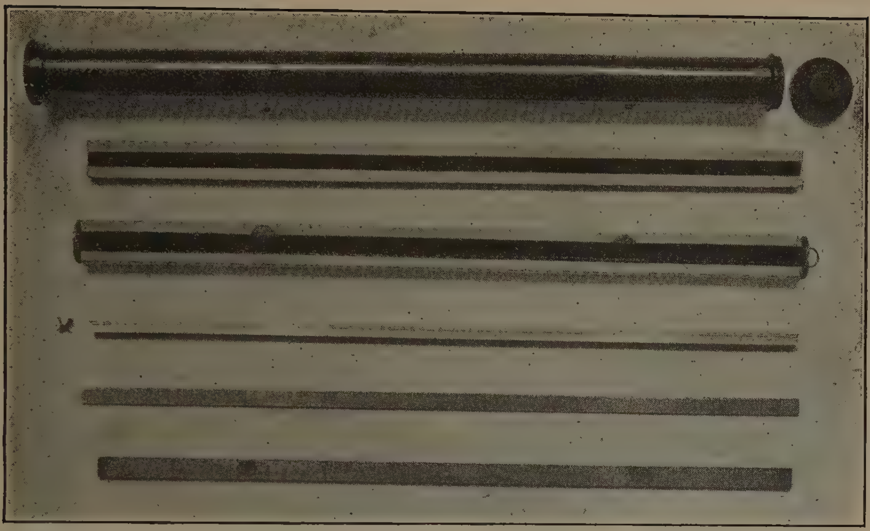


Figure 6—Standard Meter Bar

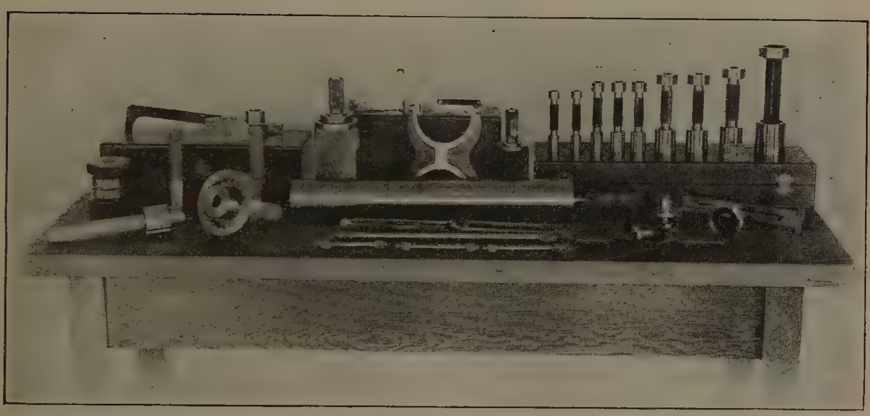


Figure 7—Types of Munitions Gages Tested

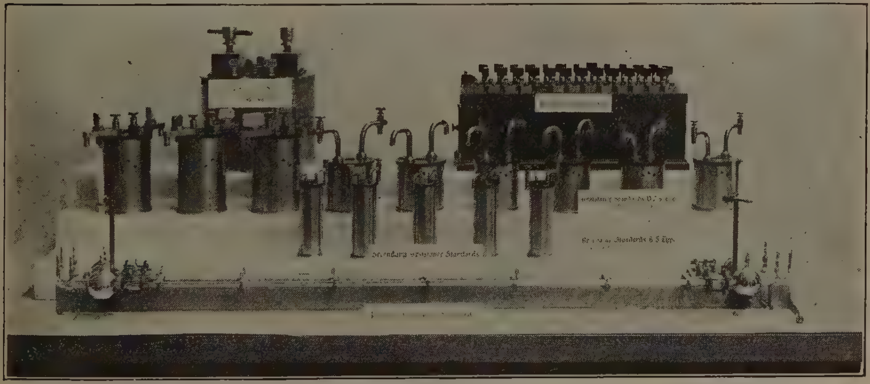


Figure 8—Standard Ohm

Figure 7 shows a number of gages that were sent to the Bureau to be tested. During the war we tested thousands of the master gages of manufacturers. This played no small part in the making of munitions on the interchangeable system and has taught manufacturers the value of such a system. The work is keeping up and the method is here to stay.

Figure 8 illustrates similar work in connection with electrical measurements. This shows a standard ohm, which has been built up by long, tedious work in the laboratory. However, it is of no use whatever to manufacturers or scientific institutions unless built up in all the

Figure 9—Thermometer Comparator

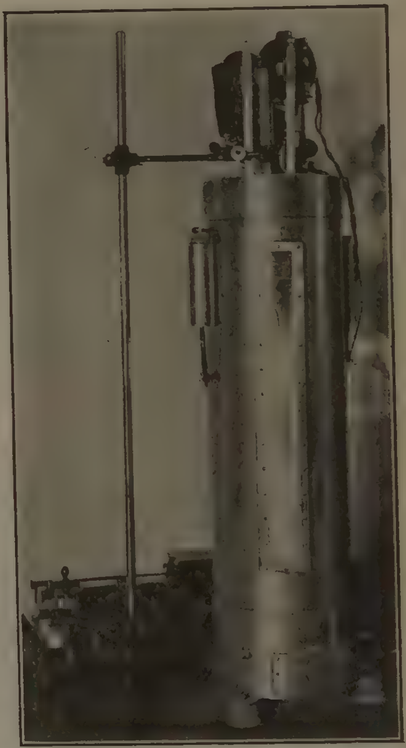


Figure 10—Low Temperature Comparator

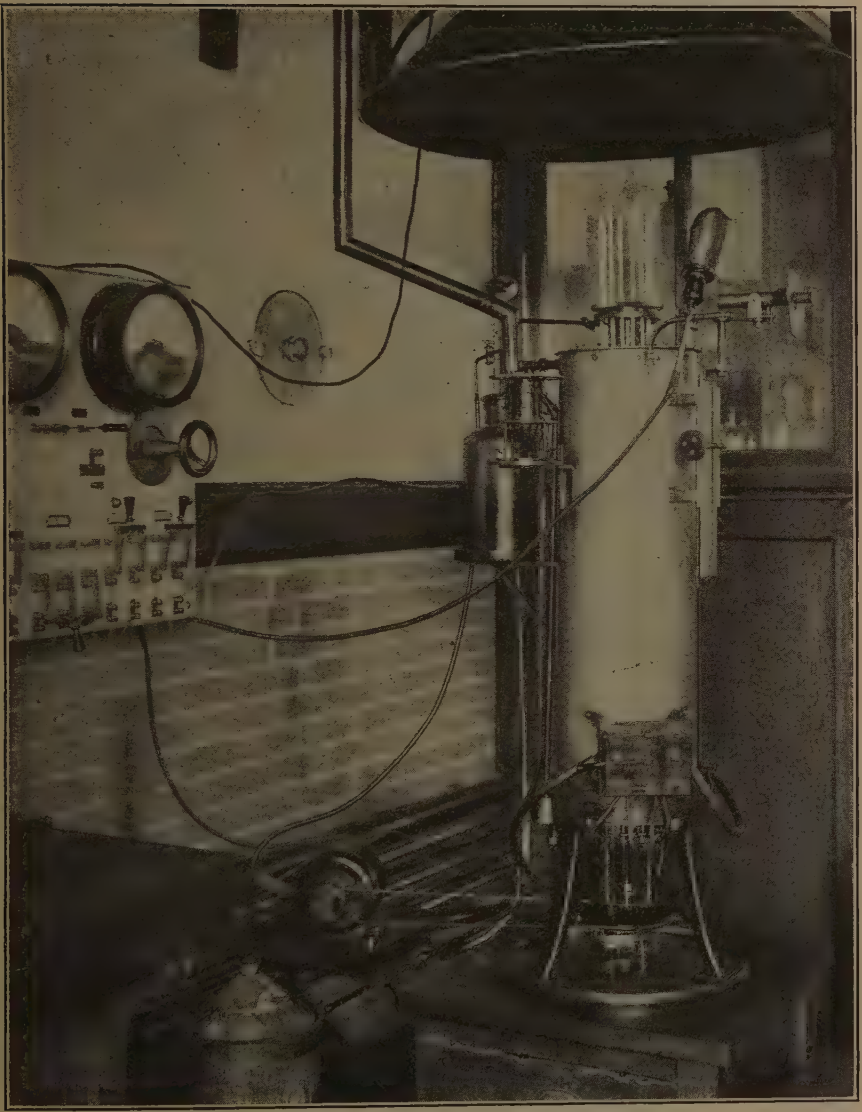


Figure 11—High Temperature Comparator

multiples and sub-multiples, corresponding to a set of weights. These working standards are shown with that of the laboratory standard.

A number of illustrations of temperature measuring instruments will be shown because they are perhaps more directly concerned with your industry. Figure 9 shows the apparatus used for testing precision thermometers. When the Bureau started its temperature work this apparatus had to be devised and built at the Bureau.

The instrument shown in Figure 10 contains liquified gases and is used for low temperature work. If we are going to test instruments for measuring temperature over all ranges, it is necessary to produce all temperatures from the lowest to the highest; the latter are produced by an electrical furnace. No other field presents so many different problems, so many different instruments, as the measurement of temperature. There are five or six men devoting their time to pyrometry, largely because it is fundamental in your industry as well as others.

Figure 11 illustrates the apparatus devoted to testing instruments used for measuring high temperatures, while Figure 12 shows the apparatus used for measuring radiant heat, known as the radiometer. This is sufficiently sensitive to measure the heat from a candle 50 miles away,

Figure 12—Radiometry Laboratory

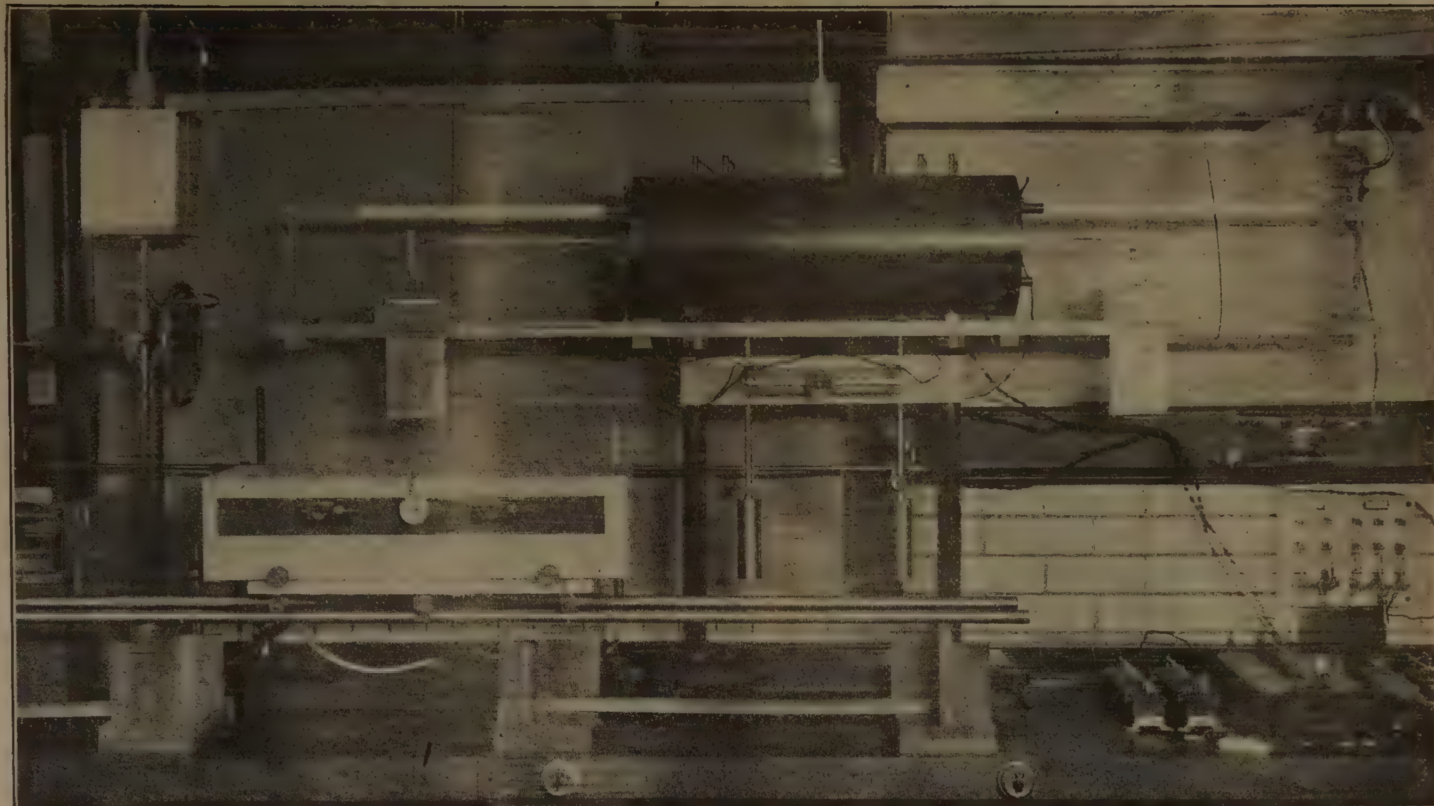


Figure 13—Apparatus for Measurement of Coefficient of Expansion

if there were no atmosphere intervening. We are often asked "Why measure these small amounts?" I remember a few years ago, when the members of the American Iron and Steel Institute visited the Bureau, we set up demonstration apparatus showing the method of measuring by light waves, and some one said "what is the use of measuring to millionths of an inch?" The answer was, "in order that we may determine laws that have an important bearing upon all physical measurements." Since then the gages just described are measured in millionths of an inch.

The apparatus shown in Figure 13 was devised for measuring coefficients of expansion. The expansion of all sorts of materials has become a very important factor, and yet very little is known of the expansion of certain materials. We have known of cases where buildings have disintegrated because of a lack of attention to the expansion of materials that are put together, terra cotta and cement, for example.

In Figure 14 is seen an apparatus for testing instruments used for the measurement of the quantity of heat. The practice of purchasing fuel in accordance with its heat value is growing, and these instruments, known as calorimeters, must be standardized and tested, as they are largely used for this work.

The following is a very interesting example of how work is grouped about a certain class of experts, and how, during the war, these experts worked on military problems without changing their fields of activity.

One of the most serious problems that was presented to us during the war was the testing of airplane engines at high altitudes, an investigation which is largely a problem of heat measurements.

Figure 15 shows an engine placed on the cradle of a dynamometer and working under ordinary conditions such as found on the ground. However, these engines were required to do their work at altitudes ranging up to 20,000 feet or over, and at very low temperatures. To

Figure 14—Apparatus for Measurement of Heat by Bomb Expansion

Figure 15—Airplane Engine Ready for Test

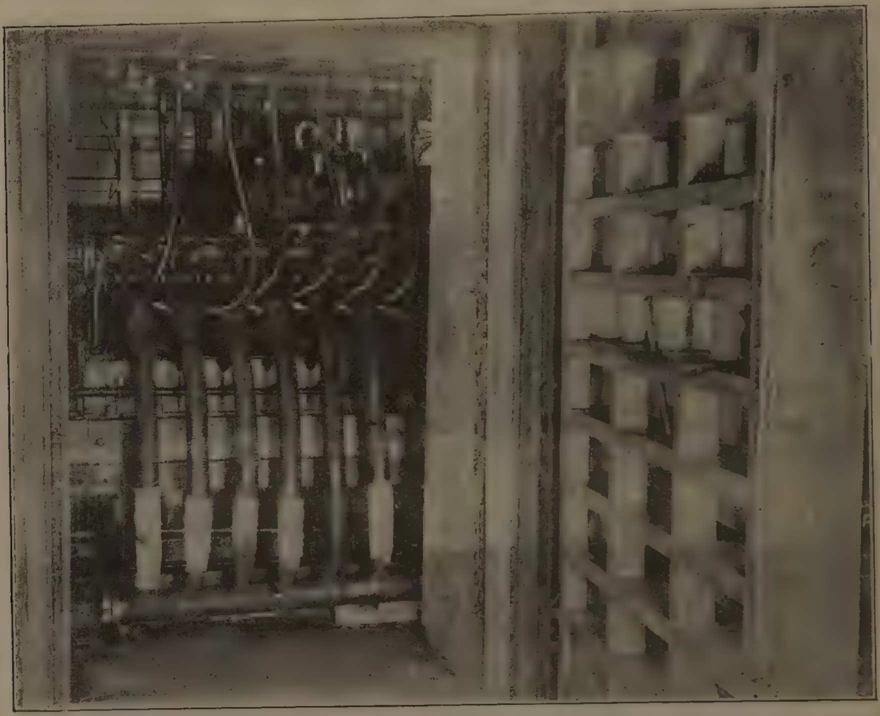


Figure 16—Airplane Engine Under Test in Altitude Laboratory

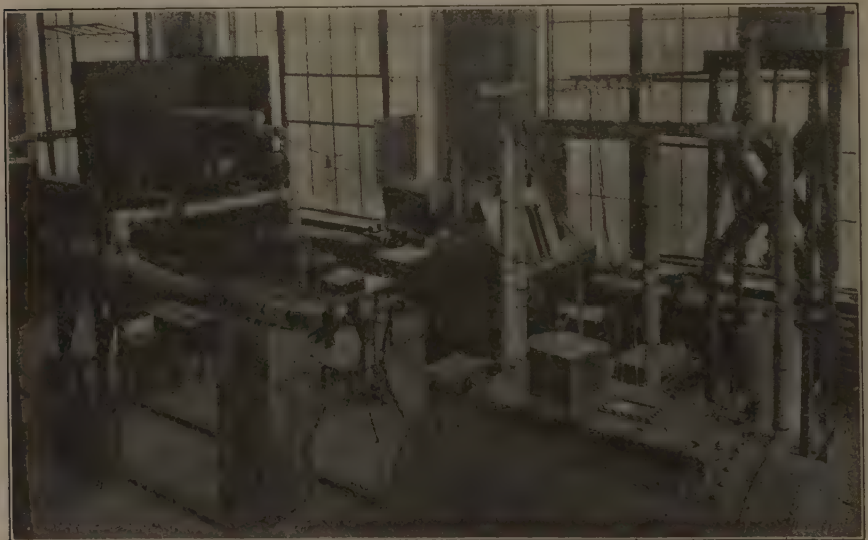


Figure 17—Radiator Testing Apparatus

Figure 18—Results Obtained by Using Sensitized Photographic Plates

meet these conditions the whole apparatus was enclosed in a large chamber of concrete, as illustrated in Figure 16, from which the air was exhausted. It was cooled by a refrigerating plant, so that the whole operation of the engine was carried on under conditions that were equivalent to an altitude of thirty or even forty thousand feet. It was an exceedingly difficult problem and required the services of physicists with broad experience in the investigation of the heat problems found in the automotive and refrigerating industries.

The same sort of apparatus used for measuring the efficiency of radiators is shown in Figure 17. Radiators are built largely according to tradition, which is quite satisfactory for automobiles, but when we are equipping airplanes with them it is necessary to take into account the laws of radiation under different conditions. The same people who did this work had been studying radiation as applied to furnaces, and the measurement of temperature.

Another example of how one can never tell what the application of a scientific principle is going to be is the use of spectroscopic photography in aviation photography.

Spectroscopists were engaged in examining and photographing the spectrum largely from the standpoint of the composition of the stars. To do this it is necessary to photograph in the red end of the spectrum. The ordinary plates are not sensitive to red light. A dye was developed which makes the plates sensitive to the red end of the spectrum. This problem was taken up in the Bureau and considerable success has been achieved in photographing with red light. The Bureau has, perhaps, made further progress than any other laboratory in this direction.

During the war the difficulty was encountered in taking airplane photographs because of haze. The two upper pictures of Figure 18 illustrates this. The red waves penetrated the fog better than others, but they are the poorest to take photographs with. However, when the

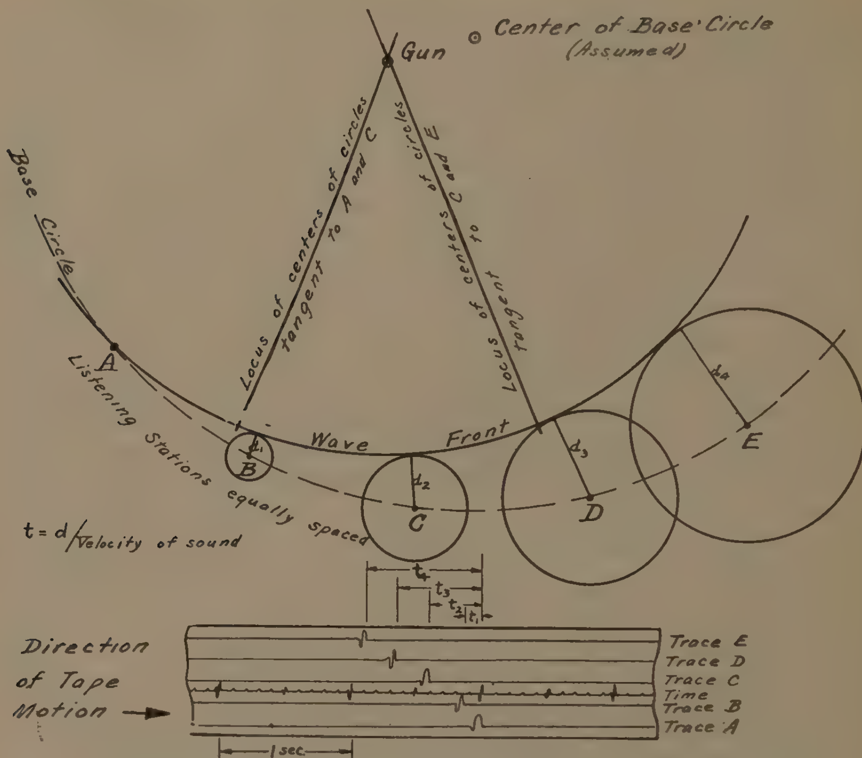


Figure 19—Diagram Showing Location of Sound Ranging Stations

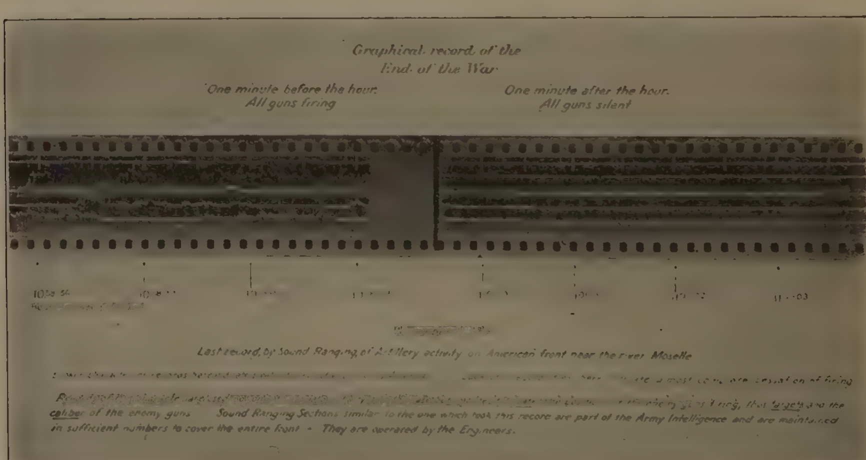


Figure 20—Graphical Record of the End of the War

red sensitive plates are used the result is as shown in the lower views of Figure 18. The spectroscopist who was working in this line was sent to France and co-operated with the Allies in this branch of photography. The time is not far distant when this method will be used in ordinary films because it gives better color values.

Figure 19 is an interesting illustration. Perhaps you have heard of finding ranges by sound, and how the Allies utilized the principle of sound in locating distant batteries by having three to six stations along the line with instruments which recorded the arrival of a sound wave from a given source, such as a gun, on a sensitive film as illustrated here. The little breaks mark the firing of a distant gun and by comparing the time that elapses between the arrival of the sound at the different stations, a line can be drawn, the center of which is the location of the distant battery. This method was used throughout the war by all of the Allies, and the Bureau was called upon to develop one particular instrument which was used with great success. Our first man sent abroad was killed while working with the British. He was, I think, the first scientific man of our forces who lost his life.

Figure 20 shows one of the regular records, and was taken on the last day of the war. The point showing the time of 10:58 and 11:00 o'clock are indicated. After that you find the straight lines; in other words, it is a graphical record of the end of the war.

In examining structural materials it is necessary to have the proper apparatus. Among other things the Bureau is equipped with an Emery testing machine as shown in Figure 21, with a capacity of 2,500,000 pounds for compression; about half of that for tension. It was largely through the efforts of the present Secretary of the American Iron and Steel Institute, when he was a member of Congress, that the necessary money was provided for the purchase of this machine. It is a precision apparatus.

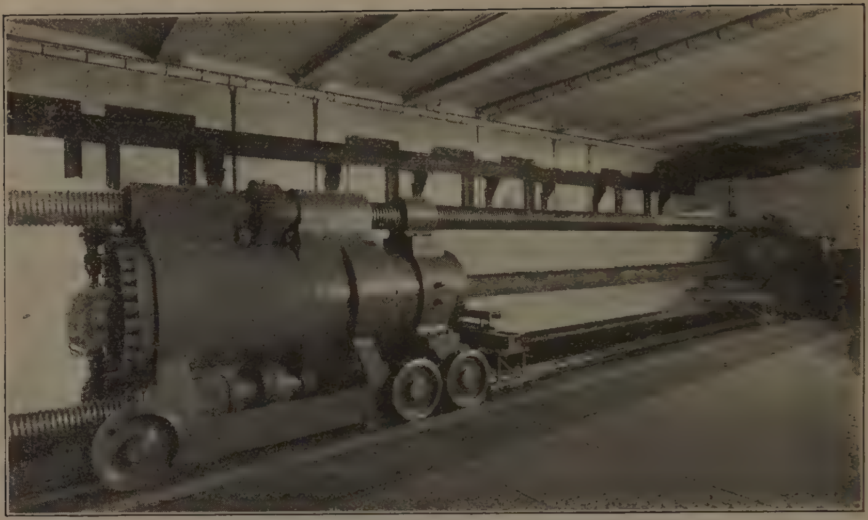


Figure 21—Emery Testing Machine

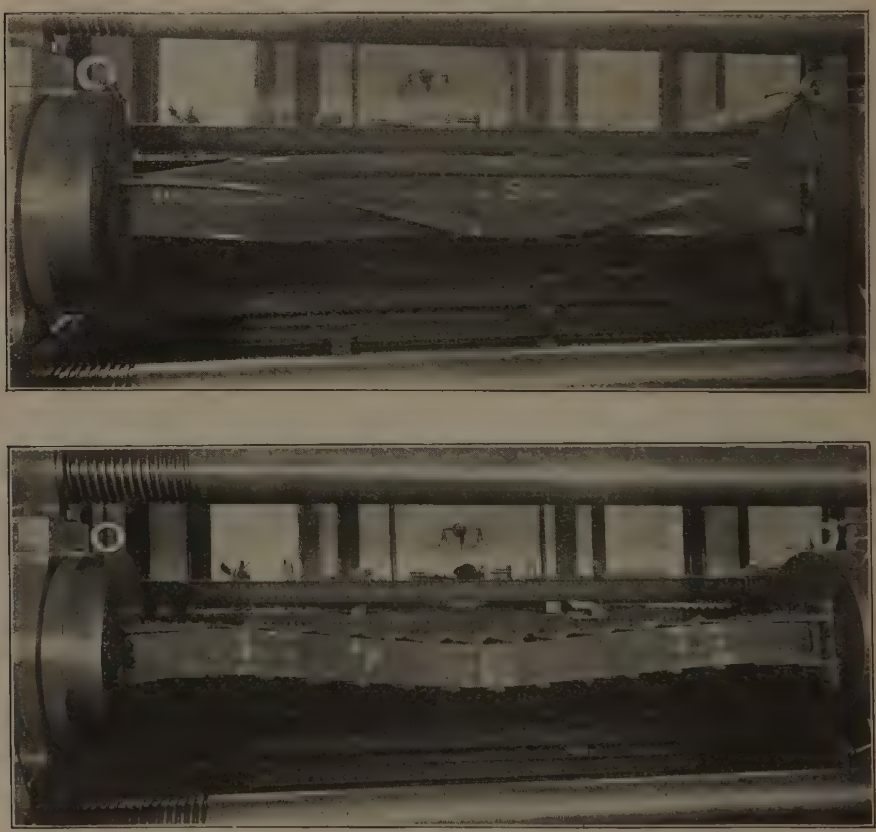


Figure 22—Tested Columns in Emery Testing Machine

The first complete investigation undertaken with this machine was on a series of columns designed according to the needs of engineers by a committee of the American Society of Civil Engineers. They were the kinds of columns that they wished to use; they specified the cross sections, the lengths, and so on. We simply did the testing. Out of that will grow the law of columns, the material for the handbook that the engineer uses in designing buildings and other structures, and where he uses steel columns. Views taken during this investigation are shown in Figure 22. During the war the entire equipment and personnel was devoted to the work of the military departments.

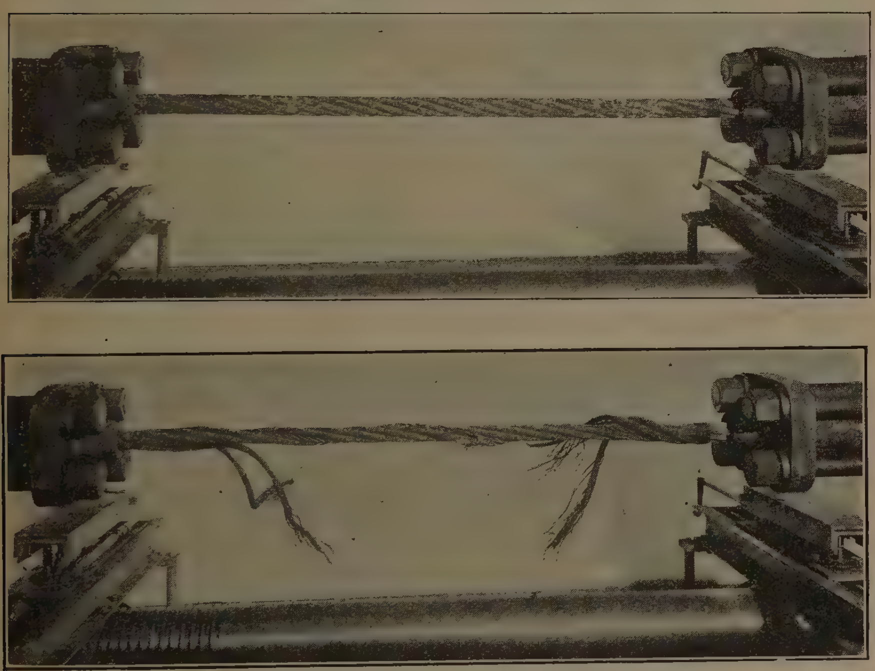


Figure 23—Wire Cable, Before and After Test

Figure 23 shows a test of wire hawser three inches and a half in diameter, which is a specimen of the cable used on the large Panama Canal dredges. You will be

interested to know that the Bureau tested practically all of the materials used by the Government in the construction of the Panama Canal.

Figure 24 is a large compression machine located at the Pittsburgh Branch of the Bureau of Standards. It has a capacity of 10,000,000 pounds for compression. The total pressure is measured by the pressure of liquid in the hydraulic cylinder. That is subject to the inaccuracy of friction, but is sufficiently accurate for many purposes. The illustration shows a brick column in the machine ready for testing.

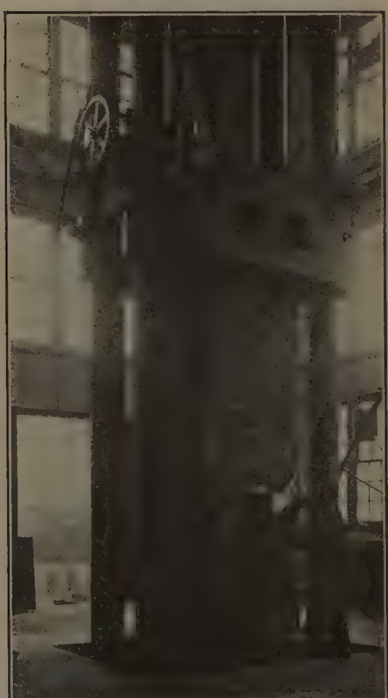


Figure 24—Large Compression Machine, Pittsburgh

Figure 25—Brick Column After Test

In Figure 25 is shown a brick column after test. A series of these has been tested, and out of that will grow the law for brick columns. We have also tested hollow

tile and reinforced concrete columns and a program is now under way for testing reinforced concrete columns under high temperatures, to show how they are affected in this manner.

The Bureau has been interested for many years in developing some of the industries in this country that were carried on solely abroad. At the beginning of the war we imported all of our optical glass and most of our optical instruments. The Bureau had developed before

Figure 26—Specimen of Optical Glass

the war the methods of making optical glass to quite an extent, at least we were in possession of the ordinary technique. There is no industry which has been surrounded with so much mystery as the making of optical glass, and the knowledge of it was confined principally to two firms, one in Germany and the other in France. At the time we entered the war, the Bureau was making glass in one large pot of commercial size. The plant was immediately enlarged to eight pots and during the war we produced two to three tons a month of good glass, such as that shown in Figure 26. This was not all that was needed, but it was quite a contribution. The point is, however, that we know the elements of that industry, and can show any manufacturer how to make optical glass. We will continue our plant as an experimental one and develop it along modern lines.

In developing this glass we found that the ordinary commercial pot would not do. The glass must not be contaminated with iron found in ordinary pots. One of the principal phases of the Bureau's work with materials, and one in which you will be interested, is that of studying refractories. A great deal of work has been done, and it should be more generally known and have a wider application than at present. The Bureau's staff having to do with refractories turned their attention to the development of the glass pot. It took a month or more to make the old pots by hand and it required a long time to season them. A method was developed at the Bureau for casting these pots, as illustrated in Figure 27. In their construction a great amount of burned material was required. For this material they went to the refuse piles of the porcelain factories, and it served the purpose exactly. This material is now quite valuable for this purpose. The new pots are cast in plaster of paris molds, just as iron is cast in sand. They can be cast in fifteen minutes and can be used at the end of thirty days, and they are just as applicable to all processes of the glass industry. The cost of making the pots as de-

veloped at the Bureau is approximately nine dollars, as compared with fifty-five dollars for that of the old type or foreign make.

In order to study these materials, especially the glass refractories, it is necessary to have suitable kilns. One of the main reasons why many research laboratories have

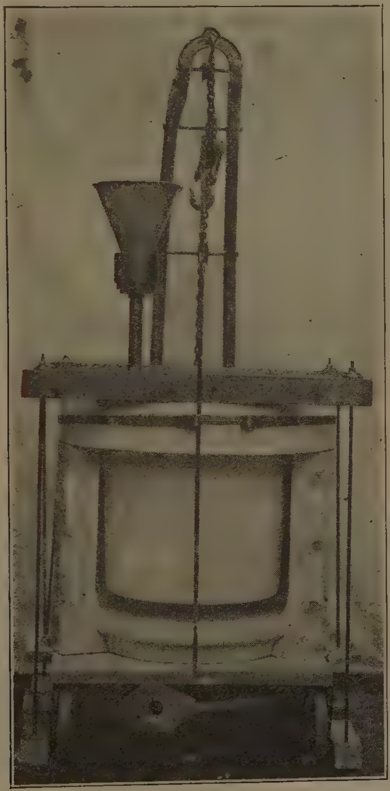


Figure 27—Optical Glass Pot Mold

not progressed further than they have is because they have never had suitable experimental equipment. You cannot stop a large mill to make the variety of products that the laboratory needs, and hence we have established at the Bureau small manufacturing units for that purpose. Generally, we have no difficulty in operating them,

but if we do the industries help us out. There is not the slightest difficulty about it, but in every case we have been told that it could not be done; yet in every case it has been accomplished, and successfully.

Figure 28 shows the ordinary kilns used in the testing and investigation of clays and the clay products. The Bureau has found these kilns very useful in securing information as to the kind of clay best suited for a given purpose; as to enamels, firing, and many other problems involving scientific data.

Figure 29 shows a small experimental cement kiln with a capacity of a barrel at a burn. I wish I had the time to tell you why we put in this mill, and how one of the bureaus of the Government insisted upon a specification which was wrong, and threw out the entire product of the Lehigh Valley district. We convinced them by putting in a small mill and burning cement with one, two, three or four per cent. of magnesia content, and up to five per cent.; it made no difference. They could not get behind that. It is a splendid illustration of how specifications should be based on truth and not tradition.

This afterwards was responsible for the changing of the specifications of the Argentine Government. They had formerly used German and Belgian specifications. There are many such stories regarding other materials I could tell you if time permitted.

Figure 30 gives a good idea of the Bureau's experimental paper machine. The Government uses a great amount of paper, and there has been considerable difficulty in the past in connection with the purchase of such supplies. In order to overcome these difficulties the Bureau of Standards installed a small paper machine. The machine has been extremely useful in varying the composition of paper and in making up known samples for testing. There are two reasons for having these experimental plants: first, to prepare samples of known composition to try out testing methods; and, second, to study the effect of each component part upon the quality of

Figure 28—Clay Furnace in Clay Testing Laboratory, Pittsburgh

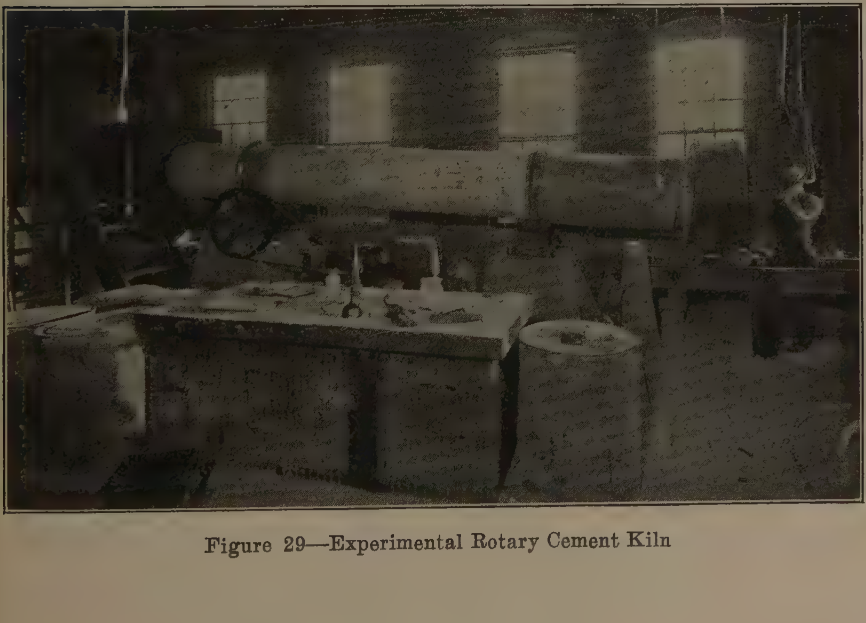


Figure 29—Experimental Rotary Cement Kiln

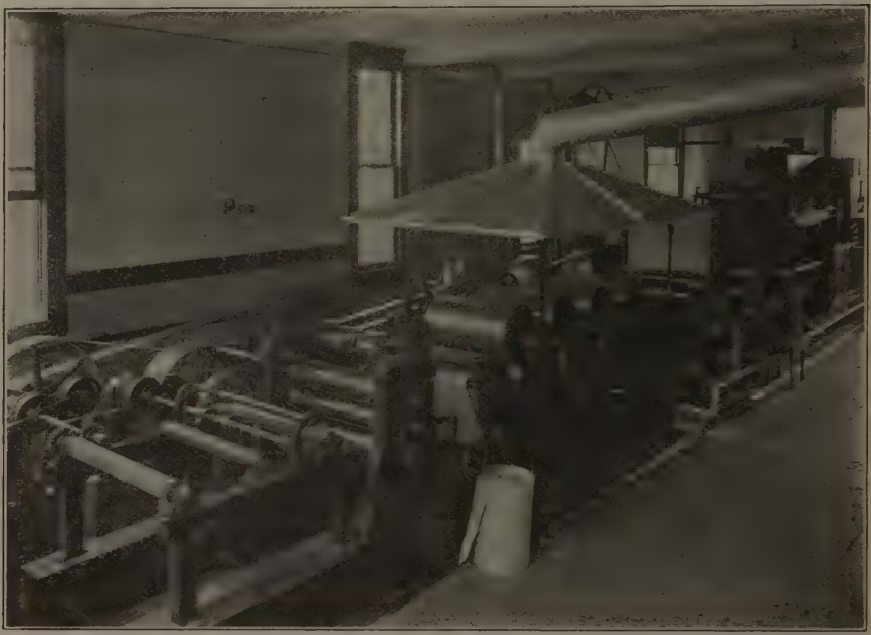


Figure 30—Experimental Paper Machine

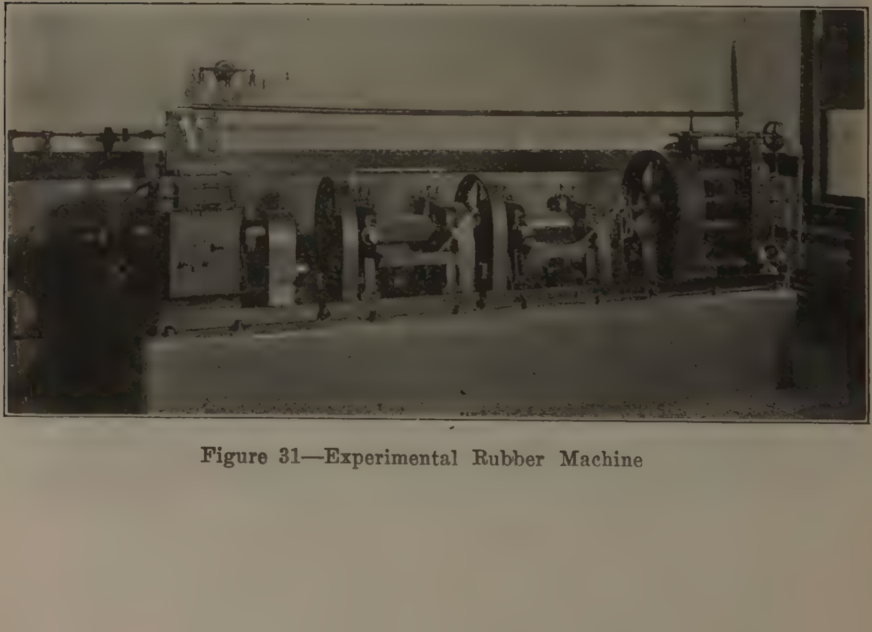


Figure 31—Experimental Rubber Machine

the material. The Bureau's idea of establishing small units for experimental purposes is being followed to a great extent by manufacturers. The same statement applies to the small rubber mill shown in Figure 31. There is perhaps no material we use about which we know as little as rubber. Here a laboratory man can compound the mixtures and find where the limits of a specification should be and not go about it blindly.

The apparatus shown in Figure 32 is a 16-inch rolling mill located in our metallurgical department. We find

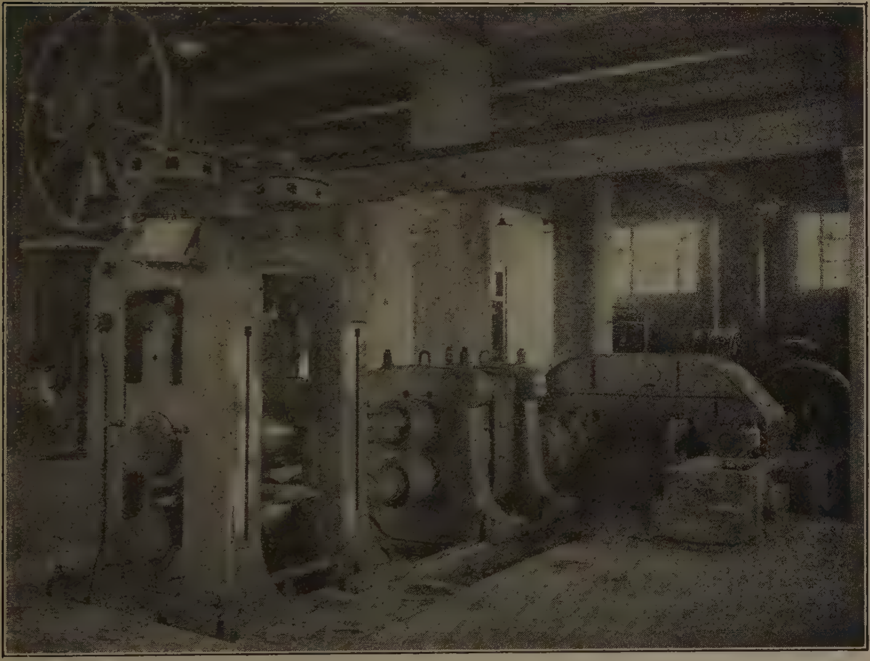


Figure 32—Sixteen-Inch Rolling Mill

that it is useless to talk about investigating these materials used in the iron and steel industries unless we can submit them to the same heat and mechanical treatment to which they are subjected in practice. The Ordnance Departments of the Army and Navy are becoming very much interested in this matter of the steel and other

Figure 33—Press in Metallurgical Department

Figure 34—View of Central Group of Buildings

Figure 35—West Laboratory

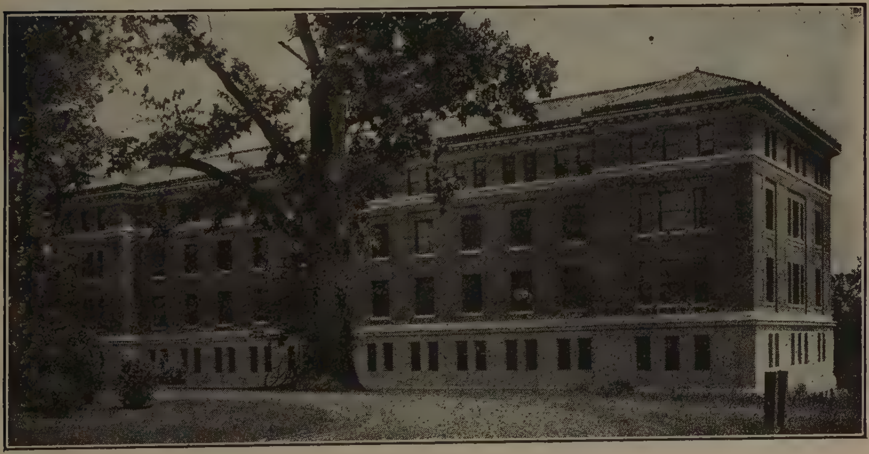


Figure 36—Electrical Laboratory

alloys. With this mill, combined with the laboratory and your assistance, it ought to make the metallurgical department of very great value to the industries of this country.

The press shown in Figure 33 was installed for the same reason as the rolling mill. It is of fairly good size and the Bureau has found it very useful in its work where the use of such equipment is employed.

Figure 34 gives an example of the type of buildings we have adopted and illustrates one of our main laboratories.

Reading from left to right—the West Laboratory; South Laboratory (Administration); Low Temperature Laboratory, including liquid air plant; and North Building, including at present the Instrument Shop and Power Plant.

Figure 35 shows the West Laboratory. The laboratories of this building are devoted primarily to the work of heat and thermometry; work in polarimetry, and at present the Emery testing machine for studying the strength of materials.

In addition to the administration offices and library on the third floor, the South Laboratory houses the Weights and Measures Division and the Optics Division. The Office Division occupies the greater portion of the third floor.

The various laboratories of the Bureau are built of reinforced concrete and of hard brick laid in cement mortar. The floor plans are practically alike in the various buildings and this type of construction answers our purposes admirably.

Figure 36 shows the Electrical Laboratory. This building is devoted entirely to the work in electricity, photometry, radium, X-ray, and radio communication. The latter work is also provided with a separate building. The building is designed with special subservice vault, high tension auxiliary laboratory, and facilities throughout for research work in electricity.

Figure 37—Chemical Laboratory

Figure 38—Northwest Laboratory

Figure 37 is the Chemical Laboratory of the Bureau of Standards. This building conforms to the general type of unit laboratory building of the Bureau—made of brick with stone trim and red tile roof.

Most of the chemical work of the Bureau is housed in this laboratory, although certain specialized branches of technologic chemistry are housed elsewhere. The chemical work of the Bureau has to do with practically every division of the Bureau, and also with the issuance of standard samples of materials and the regular routine analyses of Government materials. In addition to these, fundamental researches on chemical problems are conducted in this building.

Figure 38 shows the Northwest Laboratory. This is a building of the best factory type—concrete, faced with brick and glass, and provided for the work in metallurgy, a high speed wind tunnel, and a portion of the manufacture of high precision gages. In the basement is a foundry and experimental research rolling mill with special equipment for heat treatment. The laboratories above are especially equipped for all branches of metallurgical research.

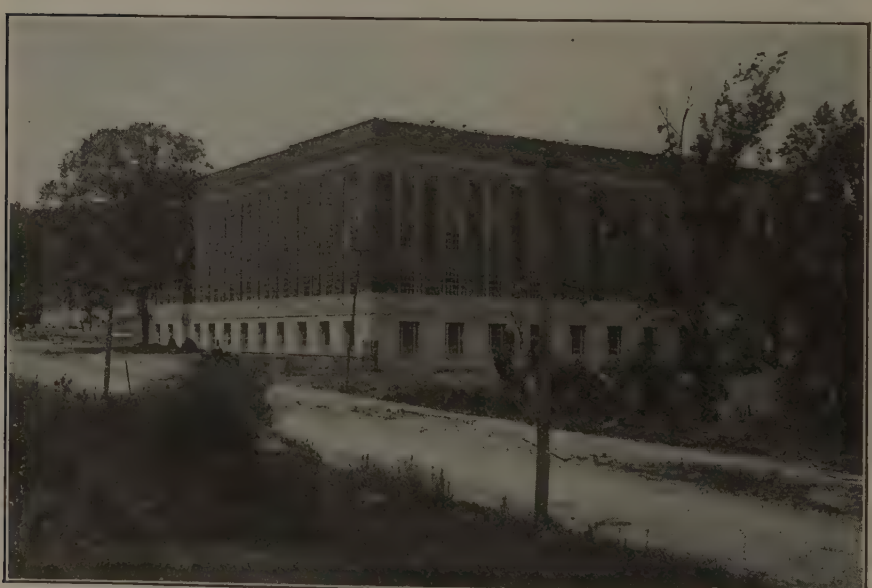


Figure 39—New Industrial Research Laboratory

Figure 40—Airplane View of Bureau of Standards

Figure 39 shows the New Industrial Research Laboratory. This building is used for engineering investigations and the technical researches having to do with materials such as concrete, stone, lime, clay products, glass, rubber, leather, paper and textiles. A kiln house running the full length of the building is provided in the rear. The building is of the best factory type and of dignified design with stone trim and with facade somewhat suggestive of pillars. The interior is designed with special reference to heavy engineering work and the facilities will be unexcelled for industrial research work within the Bureau's field. The Photographic Laboratory is also located in this building.

Figure 40 is an airplane view of the Bureau's Buildings. The buildings to the left occupy the top of a natural hill 350 feet above the Potomac River level, about three miles and a half northwest from the White House. The building on the extreme right is the latest of the Bureau laboratories and will be devoted to industrial research. The long two-story building in the middle foreground is the new laboratory for research in radio communication, in which are housed the radio researches of the War Department, the Navy Department, and the Bureau of Standards, which are conducted co-operatively.

PRESIDENT GARY: The next paper is by Mr. T. F. Baily, President, The Electric Furnace Company, Alliance, Ohio, on the subject of electrically heated soaking pits, reheating and annealing furnaces, and automatic furnaces for heat treatment, as applied to the steel industry.

ELECTRICALLY HEATED SOAKING PITS, REHEATING AND ANNEALING FURNACES, AND AUTOMATIC FURNACES FOR HEAT TREATMENT, AS APPLIED TO THE STEEL INDUSTRY

THADDEUS F. BAILY
President, The Electric Furnace Co., Alliance, Ohio

The introduction of electrically heated furnaces to the heating operations subsequent to melting and refining in the steel industry has experienced the slow development incident to the introduction of all radical innovations in any industry. Many of the types that will find wide application in the future, while entirely feasible, have, when offered, been met with the statement that if such an equipment was a good thing, why were they not in general use. Other types, that have been in regular service for a considerable number of years, whose construction and operation are much more elaborate and whose commercial advantages are no greater, are now generally accepted as the most rugged and reliable equipment for the purpose. This latter refers to electric furnaces for the annealing and heat treatment of steel.

One of these types installed some three years ago, and described more than two years ago in a paper before this Institute, has been used exclusively since its installation for the particular material for which it was designed—namely, cast steel draw bar knuckles—and subsequent to the installation of the first unit, a second unit of the same capacity was installed. This equipment has, since its installation, handled over 50,000 tons of material—approximately half of all the material of this character used on American railroads having passed through these furnaces.

The higher "fuel" cost for electric furnaces over fuel-fired furnaces that might have been used for the same pur-

pose, has been amply justified in commercial practice by the labor saving effected, the precision of the treatment produced, and the elimination of the rejections of parts due to defective heat treatment; the precision of the laboratory is obtained in regular plant practice.

There has been a reluctance of manufacturers generally to consider that there is a difference in cost per ton of material put through a furnace and the cost per ton of material heat treated and coming within the specifications. There has been no greater factor in changing this attitude than the conditions brought about during the war, where in a great many plants there was a wide difference between the quantity of material inspected and the quantity of material accepted. Manufacturers now are generally conceding the justness of the higher requirements of steel, and this is one of the greatest arguments in favor of electric furnaces.

Three conspicuous examples of the electric furnace for heat treating are those for Liberty motor crank shafts, over half of which were so heat treated; cast steel anchor chain, all of which was heat treated in furnaces of this character; and draw bar knuckles, substantially half of those which are used in America being thus heat treated.

These examples are typical of the furnaces to be described in this paper adapted to other operations in the steel industry, embracing soaking pits for the soaking of hot stripped ingots, reheating furnaces for hot blooms and billets, combination fuel and electric furnaces for the heating of cold blooms and billets, recuperative car type annealing furnaces for bars and sheets, and automatic heat treating equipments for drop forgings and castings and for the heat treatment of steel rails and similar material.

The Electric Soaking Pit

The electric soaking pit for hot ingots is perhaps the most promising development of the electric furnace to the steel maker, as the short comings of the present pits—

whether of the fired or non-fired type—are well known. and many troubles of the rolling mill can be traced to the present type of pit.

The principal recommendation of the present type of pits, either of the fired or non-fired type, is the low fuel consumption per ton of metal soaked. This cost in a well handled pit is almost a negligible item, amounting frequently to only a few cents a ton.

However, in the larger mills, when running at full capacity, features such as lack of uniformity in temperature of the heated ingot, excessive oxidation of the ingot, and the like, are often such as to quite outweigh the item of mere fuel cost; and while it is to be admitted that electric pits cannot compete with fuel-fired pits under ordinary circumstances, when heating cold ingots, the time is not far distant when substantially all modern mills rolling hot ingots will use electric pits for this part of steel mill operation.

It has been difficult to overcome the prejudices against this innovation in ingot soaking; but the advantages to be gained are so apparent, and the success of electric furnaces in other similar fields has been so marked, that it will not be long until electric soaking pits will be in commercial operation.

From electric furnaces operating at the same temperature, or at even higher temperatures than that required in soaking pits, and which have been operating over long periods of time, it is apparent that the stand-by, or wall losses, of a typical pit adapted to hold sixteen 3-ton ingots will not exceed, as a maximum, 1000 K.W., and will be expected to operate on considerably less current.

However, taking 1000 K.W. as a basis, which is amply safe, and when operating on hot ingots, whose superheated interiors are sufficient to bring to temperature their colder outer shells, and operating on a soaking time of one and one-half hours, the capacity per pit will be 32 tons per hour with a figure of 1000 K.W. per hour for the

furnace, the current consumption per ton of metal soaked would thus be 35 K.W.H. per ton; and taking as a basis of cost of electricity in the steel mill of one-half cent per kilowatt, the cost per ton of metal soaked would be 17½c. to which might be added a cost of 5c. per ton for renewals and repairs, making a total cost of 22½c. per ton for these two items.

It is to be expected that this cost for heat may be in excess of similar costs for gas-fired pits or unheated pits; but when taking into consideration that the electric pit will eliminate the roll breakages due to cold ingots, delays in the mill due to ingots unevenly heated, oxidation, thus producing a cleaner bloom and an actual saving in metal due to this elimination of oxidation, amounting to perhaps one-half of 1 per cent.; as well as the ability of the electric pit to save labor; it is certain that the higher cost will be more than offset by the advantages, and that per ton of metal rolled in a given period the actual cost by the use of an electric pit will be less than by other means.

The illustration (Fig. 1) shows the general arrangement and character of such a pit. This pit will be provided with eight holes, instead of the usual four, and in consequence only half as many ingots will be located in each cell.

The resistance elements themselves, composed, as in all furnaces of this class, of broken carbon thrown loosely into a carborundum fire-sand trough supported on brick pillars, are located along the outer wall of each side of the pit, and protected against the liability of serious accident from the ingot by being recessed some distance back from the ingot cell itself. The heat from this resistance element, it will be noted, is radiated to the circular wall of the pit, and thence to the cover, the partition wall of the pit, and to the ingots themselves. The cross section of this resistor element is such that there is very little difference between its temperature and the ruling temperature of the pit; and in actual practice most of the heating is done by the walls of the pit itself, rather than

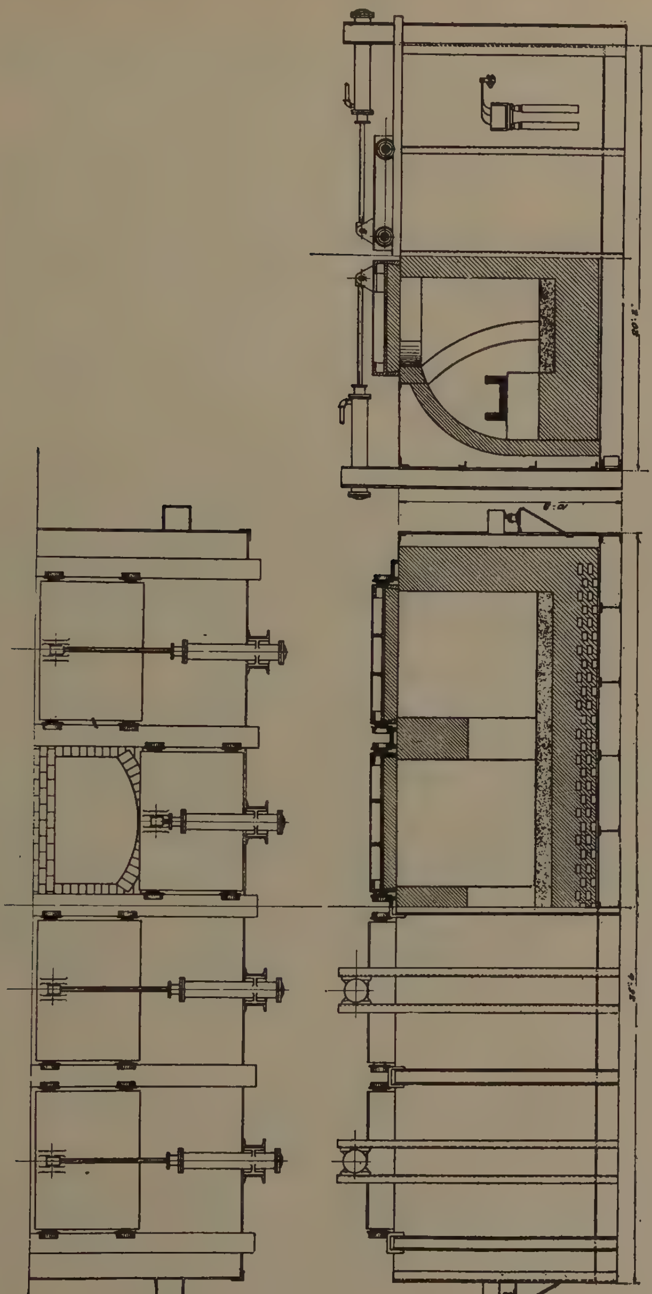


Fig. 1.—Pit Type Furnace for Soaking Ingots for Heavy Gun Forgings and Ship Shafts.

by direct radiation from the resistor element—this being of the highest importance in obtaining uniformity of heating.

In cases where the ingots cannot be delivered to the pit with enough heat for them to reach a high enough temperature without the addition of more heat from the pit itself, a longer time will be required by the ingots to bring them to temperature, and at the same time the capacity of the pit in tons per hour will be reduced.

But taking as a basis ingots whose average temperature would be 1800°F., requiring 300° additional for bringing them to temperature, the capacity of the pit would be reduced to 24 tons per hour, the electrical capacity of the pit increased to 1500 K.W., and the current consumption increased to 60 K.W.H. per ton.

While with ingots charged at an average temperature of 1500°F., the capacity of the pit would be reduced to 16 tons per hour, and the current consumption increased to 90 K.W.H., without increasing the electrical capacity beyond 1500 K.W.

Thus we have for a total of heating costs, including the renewals and repairs, and with power taken at ½c. per K.W.

For Hot Ingots	22½c. per ton
" Ingots at 1800°F.	35 " "
" Ingots at 1500°F.	50 " "

the final temperature in each case being taken as 2100°F.

These figures can be safely taken as guarantees, and it can be expected that they will be much bettered in actual practice and operation over long periods of time.

Continuous Type Reheating Furnaces

It is believed that this type of furnace will find wide application in the heating of cold steel for forging and rolling in relatively small capacities, and in reheating steel of high quality; but where very large tonnages of cold blooms or billets are to be heated, a combination fuel

and electric furnace—to be later described—will be better adaptable for such work.

Figure 2, illustrates an all-electric billet heating furnace.

This furnace was built for heating 3¼″ round billets for shell forgings, and while the current cost for supplying this particular furnace was high, and the operating conditions not particularly favorable, nevertheless the reduction of rejections of forgings due to eccentricity, the saving of the dies due to the elimination of scale, and other advantages, such as better working conditions and

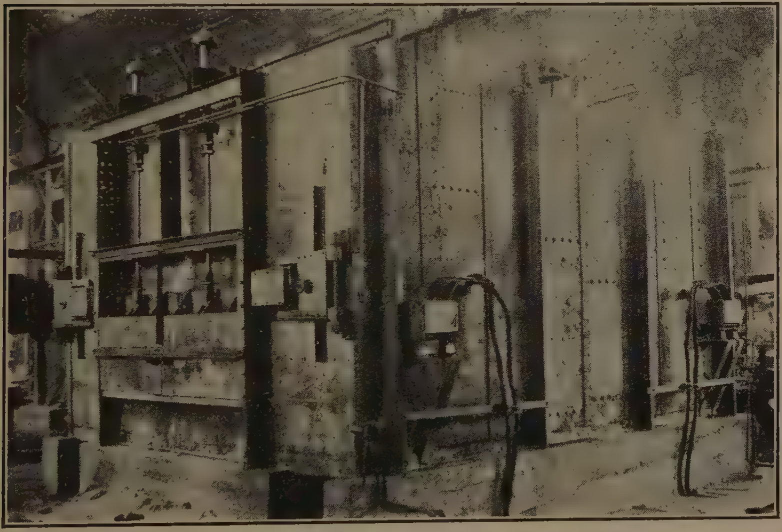


Fig. 2.—Billet Heating Furnace (all-electric).

simplicity of control, enabled the results to compare favorably with coal-fired practice.

This furnace was of 600 K.W. capacity, and in actual practice handled 1½ tons of steel per hour, with a current consumption of a little over 450 K.W.H. per ton, or a thermal efficiency of a little more than 50 per cent. Under more favorable conditions, an efficiency of 66 per cent., or a current consumption of approximately

300 K.W.H. per ton has been obtained. So that with low cost of current, which it is believed may be taken as ½c. per kilowatt in steel mill power costs, the fuel cost for cold heating in units of this size would be $1.50 per ton.

This cost will compare favorably with direct coal-fired furnaces of similar capacity, and will actually show some commercial advantage, when taking into consideration the saving in metal due to scaling, which may readily run several per cent., and at least in average operating conditions may be taken as 2 per cent., and under the worst conditions 5 per cent., which has been actually observed in one or two instances.

Furnaces of larger capacity than the one described, of course, show a less favorable comparison to the electric, and furnaces of smaller capacity show a more advantageous comparison with the electric furnace; and it is believed that in any case, the cost of material heated in furnaces of this size, all things considered, may be safely taken as running very close together, with the electric furnace having the advantage in greater uniformity of temperature and other incidental advantages, including a higher yield of good finished pieces.

An application that it is believed will find favor in certain steel mill operations is the use of an electric furnace for reheating billets for finishing mills, wherein the blooms or billets coming from one mill are too cold to put into the finishing mill and will require approximately 200° additional heat.

The calculations on such an equipment are as follows; for a capacity of 15 tons of 4″ square billets per hour, charged into furnace at 1800°F. and brought to 2000°F., such a furnace would require 800 K.W. per hour for its operation, and somewhat under 60 K.W.H. per ton of metal reheated, and with ½c. for power, this would make a cost of 30c. per ton of metal thus reheated. As an electric furnace of this character would undoubtedly save one-fourth of 1 per cent. of metal over fuel-fired furnaces, which would amount on steel worth $40.00 per ton to a

saving of 10c. per ton, and then taking into consideration the low efficiency to be expected of a fuel-fired furnace of this character operating on hot billets only, there would be a decided advantage in the use of the electric furnace for such an operation.

Combination Fuel and Electric Reheating Furnaces

Where large tonnages of cold blooms and billets are to be heated, however, unless electricity can be obtained at an exceptionally low rate, and fuel can only be had at

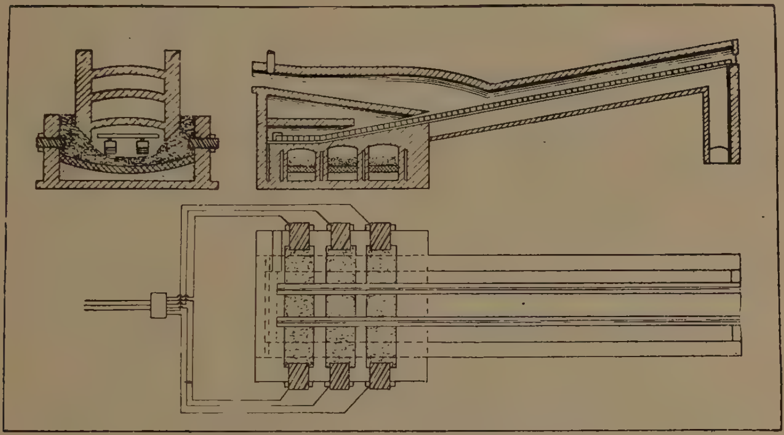


Fig. 3.—Combination Gas and Electric Billet Heating Furnace.

a high cost, a combination gas and electric furnace, such as shown in Figure 3, wherein the earlier stages of the heating up to say 1800°F. are handled by fuel, and the final temperature handled electrically, is perhaps the only type that can compete with the continuous fuel-fired billet heating furnace.

Such a combination would enable the preliminary heating to be done with fuel, without danger of excessive oxidation that is present in the fuel-fired billet heating furnace, and will insure a uniformity in the heating of the billets that is not generally obtainable in fuel-fired furnaces of this type; and while there would be a small saving of perhaps fifty pounds of coal per ton of metal

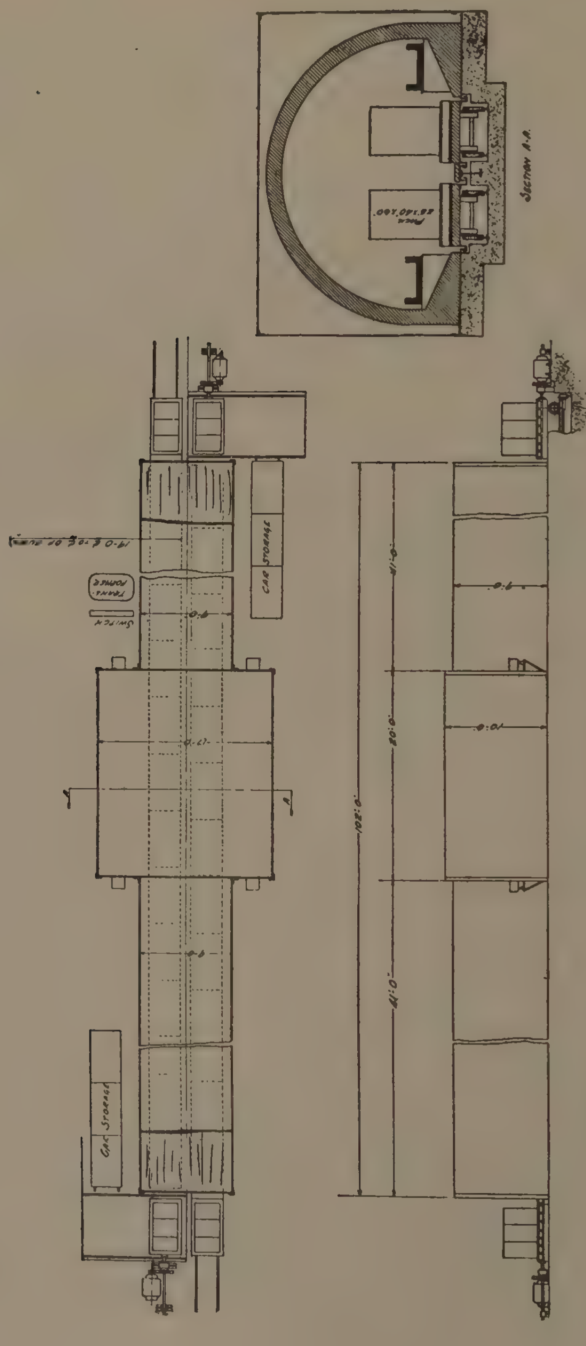


Fig. 4.—Continuous Recuperative Car Type Annealing Furnace for Annealing Tinplate, Cold Rolled Strip Steel and Similar Materials.

heated, due to the lower temperature to which the billets are heated by the fuel-fired end, against this must be charged, say, 60 K.W.H. per ton of metal, or 30c. per ton of metal heated for the final stage by electricity; nevertheless, the advantage of uniformity in temperature, elimination of scale, etc., and more accurate control, will justify in many cases the use of such a combination furnace.

Annealing Furnaces

Of the annealing furnaces in the steel industry, the recuperative car type will have perhaps the widest application. Two furnaces of this type are now under construction. The largest of these will have a capacity of 150 tons per day when annealing at 1200°F., and is adapted for the annealing of cold-rolled strip and sheets. The second furnace, though having approximately the same dimensions, will be for annealing alloy steel bars, which require a long soaking time at maximum temperature.

The first of these furnaces is shown in Figure 4. One notable feature of these furnaces is that the annealing will be done without the usual covers required in fuel-fired furnaces ordinarily used for this work, which will constitute one of the greatest savings in annealing, as compared with present methods. This recuperative type furnace lends itself to the highest economy, as after the steel has reached the full temperature and is passing toward the discharge end of the furnace, a large part of this heat is given up to the cold incoming material.

In the preliminary trials of the first of these furnaces, excellent annealing results were obtained, as well as high economy; but difficulty was experienced with the equipment from the standpoint of complete elimination of oxidation, due to a lack of proper precaution at the ends of the furnace. This matter, however, is one readily overcome, and this equipment will soon be in regular operation.

The equipment illustrated in Figure 4 is of 600 K.W. electrical capacity, and is approximately 225′ long x 22′ wide. The material is handled on sand-sealed cars, each car being substantially 13′ long x 4′ wide, and adapted to hold 20 tons of material, there being in all seventeen cars located on each of the two lines of track passing through the furnace, each line of cars passing in opposite directions. In the middle of the furnace is located the heating chamber proper, which is 26′ long, holding two cars in the heating zone on each track at a time, or substantially 80 tons of material at a time in the heating chamber.

A movement of the cars takes place on each track approximately every six hours, discharging at that time two 20-ton cars of material, one at each end of the furnace, and similarly charging at each end of the furnace a car of cold material. The cars are moved forward by means of a hydraulic machine, operated by a 600-pound water pressure system.

One of the requirements of this equipment is that when annealing low carbon cold rolled strip, the hardness should not exceed 20 scleroscope measurement. All of the tests taken were between 18 and 19.

While no tests for maximum capacity could be taken at the time, owing to sufficient steel not being available, the operation at half capacity was well within 200 K.W.H. per ton, which clearly indicated that when operating at full capacity the current consumption would be somewhat under 120 K.W.H. per ton.

Taking again large steel mill practice of current at one-half cent per kilowatt, the cost of annealing in this type of furnace would not exceed 60c. per ton, which will compare favorably with coal-fired annealing furnaces from a fuel standpoint, and in addition will completely eliminate the expense of covers, as well as a considerable amount of labor and will introduce a precision in annealing that is not possible to obtain with present equipment.

The other equipment of this character, although of approximately the same dimensions, excepting being some-

what shorter in length, requires a larger heating chamber proper, even though the rated capacity is only 75 tons per day. This is due to the fact that the metallurgical requirements are such on the alloy steel to be treated that the material must be soaked for forty hours at a maximum temperature of 1400°F.

The furnace itself is supplied with 800 K.W. transformer capacity, and will operate with a current consumption something under 250 K.W.H. per ton of metal annealed. In this furnace ten 15′ cars, each holding 30 tons of material, are located on each of the two tracks, and a maximum of 600 tons of material is in the furnace at a time, 120 tons of which are in the heating zone proper. The full movement of each line of cars will take place substantially every twenty hours, delivering substantially 72 tons per day.

One of the special requirements of this furnace is that the cooling from maximum temperature over the first 200 degrees of the cooling range must not take place at a greater rapidity than ten degrees per hour. This necessitates the introduction of a very powerful and slow pulling mechanism, wherein the speed of travel does not exceed nine inches per hour.

This special equipment consists of a motor-operated chain haul, similar to the equipment used in the larger types of draw benches for tube drawing, and is supplied with a 10 H. P. motor through seven gear reductions. As the cars must pass through a sealed entrance hood or chamber before going into the furnace proper, this precaution being found necessary in order to prevent reducing the atmosphere of the furnace during charging, the pushing mechanism and the door operating mechanism are interlocked, so that when the push button starter is operated the interlocking mechanism first raises the door of the entrance hood, then the cold car of material is pushed into the chamber, the entrance door closed, the door to the main furnace next opened, the pusher continuing the push of the car just far enough into the entrance

hood until it comes in contact with the main line of cars in the furnace. From this point on, the travel is at the rate previously mentioned, namely nine inches per hour, during which time the door at the discharge end of the same line of cars at the opposite end of the furnace is opened, and the car at the discharge end moved into the cooling hood at that end, the discharge door on the vestibule itself still being closed. When the cold car being pulled in has come fully within the door line of the furnace proper, the door is dropped behind it and the heating chamber thus sealed.

At this point, the pushing dog behind the car is reversed, and it is returned to its starting position to bring another car into the entrance hood. While doing so, however, a pull-out chain, operated by the same shaft as the main pulling drum, latches, through means of a special dog, into the car of cooled material on the opposite track, moving it a few inches forward from the line of cars that has pushed it to the discharge position, then the interlocking mechanism drops the door in front of the line of cars, after which the outer door of the vestibule is opened, and the drawback mechanism pulls the car entirely clear of the furnace, at which time the door of the vestibule is closed. Immediately following this operation, a similar operation to the one just described begins at the opposite end of the furnace, the chamber and the furnace proper being first opened.

Heat Treating Equipments

It is, however, in heat treating equipments—which consist of two furnaces, one for the hardening temperature and one for the drawing temperature, in connection with a quenching mechanism located between—that electric furnaces have been first recognized as standard equipment for exacting work in the steel industry, and the earlier of these furnaces, especially of the automatic type, have been in use now for several years.

One of the most notable of these is an installation

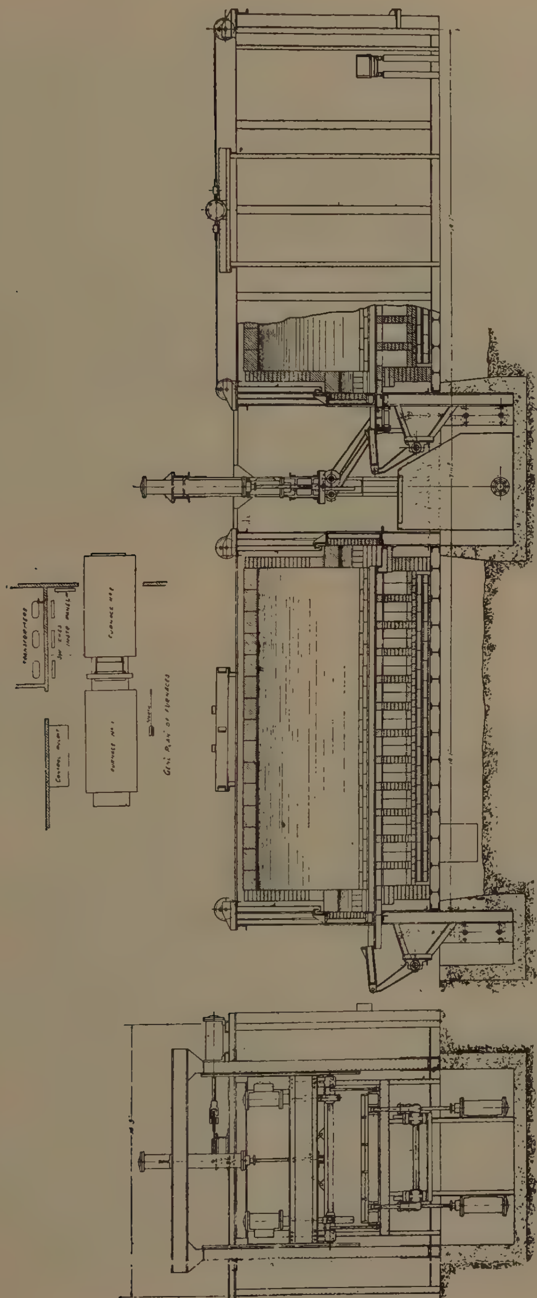


Fig. 5.—Continuous Automatic Two-Furnace Heat Treating Equipment, Hydraulically Operated, for Heat Treating Drawbar Knuckles and Airplane Cranks.

Fig. 6.—Electric Furnace Equipment for Heat Treating Crankshafts.

Fig. 7.—Electric Furnace Equipment for Heat Treating Crankshafts.

made at Sharon, Pa., over four years ago, which the following year was augmented by a duplicate installation.

A similar equipment of the same capacity was installed last year for the heat treatment of crank shafts for the 12-cylinder Liberty airplane motors. This equipment is shown in Figure 5. On account of the irregular shape of the material under treatment, and also to enable other sizes and types of airplane shafts to be handled interchangeably, a special type of cast steel chair was developed, so that the direct force of the pusher is brought against a line of these chairs, the material to be heated thus lying independent and free from strain while going through the furnace.

The steel used in these crank shafts was perhaps one of the most difficult to heat treat, and the requirements were most exacting. Opportunity for obtaining the exactness of this treatment was in this case readily available, as test pieces were taken from each end of every piece, and it is interesting to note in connection with this rigid inspection that for days at a time, when producing even several hundred cranks a day, there would not be a single rejection for any cause. This fact not only speaks well for the heat treating equipment but for all the previous operations in connection with steel, including the forging, heating for forging, and the making of the steel itself.

Anchor Chain Heat Treating Furnaces

A heat treating equipment of similar capacity, but with a modification as to handling mechanism, is installed at the plant of the National Malleable Castings Company, Cleveland, Ohio, for the heat treatment of cast steel anchor chain. This consists of a 600 K. W. hardening furnace, approximately 28′ long x 16′ wide, and a hearth the full length of the furnace and 6′ 6″ wide. At the discharge end of this furnace is located a concrete quenching tank, 40′ long x 8′ wide for quenching the chain. At the other end of this pit is a furnace of similar size, but of 300 K. W.

capacity for drawing the temperature of the chain after quenching. Each of these equipments has a rated capacity of 50 tons of chain per day, and the current consumption when operating at capacity is substantially 450 K.W.H. per ton, this current consumption being 150 K.W.H. per ton higher than in the other heat treating furnace just described and than the two similar sets at the same company's Sharon plant, due to the fact that the material is such that a larger furnace chamber was required for a given capacity.

The charge of material consists of two 90-foot lengths of 2-inch cast steel anchor chain, folded into loops 22′ long. These loops are dropped over heavy cast steel hooks, the end of which, when the charge is in the furnace, protrude through recesses cut in the furnace door. The ends of these hooks are connected to a heavy steel cross bar, which is provided with lugs for fastening on the pulling chains, operated by a heavy winch, similar to a crane drum, and equipped with a 20 H. P. motor. One of these winches is located 30′ beyond the discharge end of the drawing furnace, the other directly over the quenching pit.

The operation of heat treating these chains begins by dropping the loops of the folded chain over the hooks in front of the charging end of the hardening furnace, the hearth of the furnace being level with the foundry floor. The pulling chains are dragged through the hardening furnace from the front end by means of a light iron bar, the winding drum backing off the chain as it is pulled through. These chains are now hooked onto the steel cross bar of the cast steel hooks just mentioned, the winch reversed and the chain pulled into the hardening furnace, where it remains for substantially two hours, during which time it is fully and entirely heated to the furnace temperature, which is about 1650°F. The doors of the hardening furnace are then opened, and the winch pulls the chain out of the furnace into the quenching pit, where it lies on a steel framework composed of 7-inch channels.

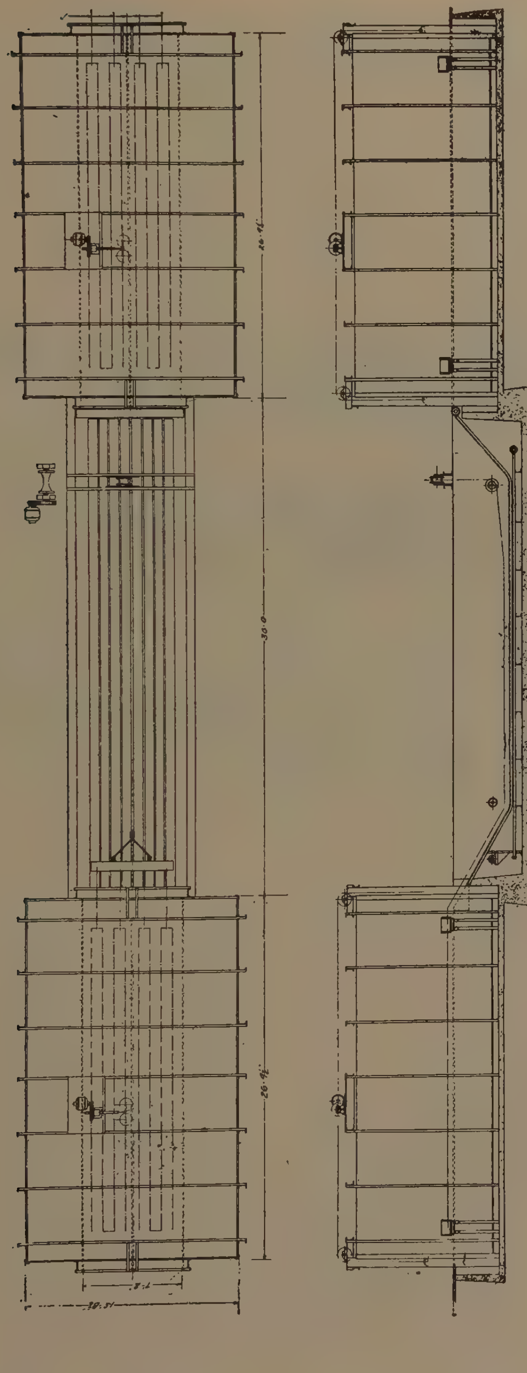


Fig. 8.—Continuous Two-Furnace Heat Treating Equipment for Heat Treating Cast Steel Anchor Chain.

As the chain is immersed into the quench, it is met by a strong flow of fresh water from submerged nozzles, so as to give it an initial chilling, directly as it is immersed. As the tail ends of these chains pass out of the furnace door, the door closes, and the chain is allowed to lie in the quench for several minutes. Before it is completely cooled, however, the chains from the winch of the second furnace are dragged through that furnace and hooked into

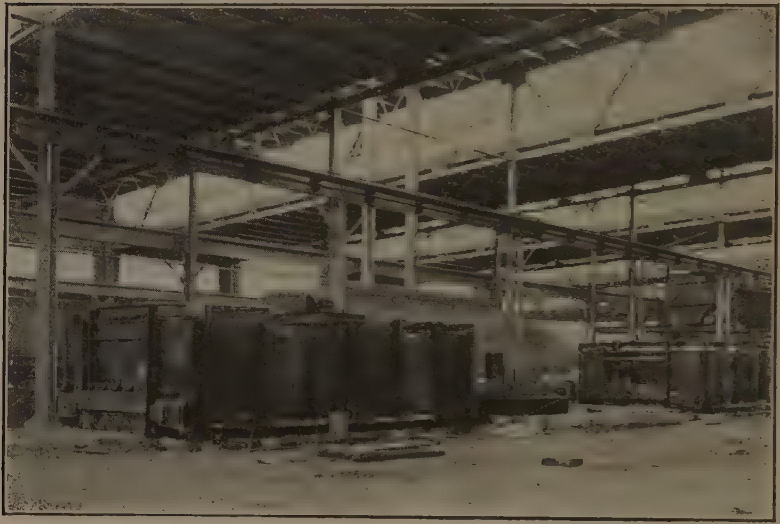


Fig. 9.—Continuous Two-Furnace Heat Treating Equipment for Heat Treating Cast Steel Anchor Chain.

the cross member and hooks holding the chain in the quench. The pulling chains from the first furnace are disconnected, the doors of the second furnace are opened and the winch of the second furnace pulls the chain into the drawing furnace, where it remains for another two hours, and is subsequently and in a similar manner withdrawn from that furnace.

Large heat treating furnaces of the automatic type such as are described in this paper, whose certainty of operation and precision of treatment have been clearly observed over several years, justify the consideration of the

heat treatment of large tonnages of heavy material, such as steel rails. The building of equipments for such purposes presents no serious difficulty.

It is readily apparent to anyone interested in this subject that the heat treatment of rails is highly desirable, as the increased physical properties readily obtainable by a proper heat treatment are such as to very remarkably increase their efficiency, not only adding to the life from the standpoint of wear, but adding materially to the ultimate strength and the elastic limit, without appreciably sacrificing the ductility or toughness; and the only real question that can be raised is whether successful heat treating equipments can be found wherein every rail treated will have exactly the heat treatment specified, and whether such equipment can be rugged enough to operate with precision over long periods of time, and the cost of operation come within a reasonable commercial range.

The furnaces described in this paper, especially those of the automatic type, which have records of years of successful service, I believe fully answer the question as to precision and reliability.

As to the special requirements of an equipment for the handling of rails, this will require, of course, a rugged quenching mechanism that will prevent a 33-foot rail section from twisting during the quenching, and perhaps a similar mechanism after the drawing operation.

Such an equipment will have the advantage of complete elimination of the gag press operation now admitted to be one of the principal undesirable operations in the making of steel rails.

As to the commercial cost of the heat treating operation, as compared with the increased physical properties, it may be stated that the actual cost for electric heat under the conditions named in this paper would not exceed $1.50 per ton, and the labor cost would probably be no more, and perhaps less, than is now required in the straightening press operation above referred to. The ultimate strength of the rail would in all probability be increased

more than twenty-five per cent., and the elastic limit perhaps doubled, while the life of the rail from a wearing standpoint would undoubtedly be materially increased. I believe it is a conservative statement to say that a twenty-five to fifty per cent. more effective rail from a wear and safety standpoint could thus be obtained at an additional cost per ton of not to exceed five per cent.

The equipments described in the latter part of this paper are the forerunners of electric furnaces of the type that will soon come into regular use for operations on a far larger scale than will generally be conceded by the average steelmaker today, and will embrace the wide and almost exclusive use of certain types, such as the soaking pit and certain forms of the reheating furnace first mentioned in this paper. While in some cases there will be an actual reduction in cost of operation over present methods due to the electric furnace, even for steel of average quality, the more rigid requirements in finished product will in some cases compel the use of electric furnaces.

Where requirements of the steel specified must be met, a lower cost may readily be found when operating electric furnaces, when taking into consideration the difference between the cost per ton of material put through the furnace, as compared with the cost per ton of material meeting the specifications.

Many of the arguments used against the introduction of electric furnaces were used against the introduction of large motors in the steel mills, and against electric haulage, and the statements frequently made through all the years about any innovation that "it has not been done and it cannot be done" must gradually yield, as one by one the various types of electric furnaces from heat treating equipments to soaking pits go into regular, commercial and economical service.

President Gary: There are two papers discussing this address, but the authors are not present. The papers will be recorded, unless their reading is called for.

ELECTRICALLY HEATED SOAKING PITS AND HEATING FURNACES

Discussion by J. W. Richards

Professor of Metallurgy, Lehigh University, Bethlehem, Pa.

Mr. Baily's paper has two outstanding characteristics: First, the careful record of very successful practice already initiated; second, the modesty with which he forecasts the extension of these methods in the steel industry.

Mr. Baily has wisely compared the cost of electric heating with that of fuel heating under conditions most favorable to the latter. He has assumed almost a minimum cost of fuel, and therefore the least favorable conditions for its replacement by electric heating.

On the other hand, he has assumed the cost of electric power at ½c. per kilowatt hour, at which price it can be generated in almost any steel works district, and has left to be inferred the greater economy of electric heating where electric power may be obtained at lower figures, such as 0.4c. per kilowatt hour in the neighborhood of Niagara Falls, and 0.3c. per kilowatt hour near still cheaper water powers.

We must not overlook the fact that steel mills have been built where fuel was cheap, which is, generally speaking, where cheap hydro-electric power is not available. We should consider the possibilities open by using Mr. Baily's electric heating furnaces at points where fuel is dearer and electric power cheaper than the figures he quotes; that is, the possibility of extending the methods to regions considerably removed from cheap coal. As an extreme example, the Girod steel works at Ugines, France, is far removed from cheap coal, but is run entirely by very cheap electric power. They should use none other but these electrically heated furnaces. In between this and the ordinary practice at steel producing centers are many works which will find it immediately profitable to install the electric heating furnaces.

A second point I wish to make is, that Mr. Baily makes a very liberal allowance for stand-by, or wall losses in his furnaces; he assumes 1,000 kilowatts as necessary to simply hold the temperature in a 16-ingot, 36-ton soaking pit. It is entirely proper for him to make this liberal allowance, but I am confident that a scientific study of the construction of the walls of the soaking pit, and particularly of the radiating surface of the outside of these walls, will reduce this figure very considerably—perhaps even cut it in half.

Iron and steel men do not pay a fraction of the attention which they should to reduction of radiation losses from furnaces and very hot apparatus. They paint surfaces black, the best color to radiate heat, when they should be painted white. They smile the sarcastic smile of contented ignorance when it is suggested to them that heat losses can be largely diminished by proper attention to the radiating surface. Tell a foundryman that heat could be saved in sufficient quantity to pay well, if he had the outside of his furnaces nickel-plated and kept them bright, and he would probably regard his informer as demented. Yet in many cases the statement would be true, and doubly true of electric furnaces.

I strongly urge the use of white aluminum paint as one step in reducing radiation losses on furnaces. Some of our laboratory furnaces are encased in polished Monel metal; it would undoubtedly be well to encase steel works electric furnaces in this manner. Even bright nickel-plating of ordinary iron shells would in most cases pay for itself in heat saved in a short time.

I plead with practical men not to ignore these "laboratory" suggestions; they are practical, and they will save money. Mr. Baily's whole article is a demonstration of the possibility of extending the precision, accuracy and economy of laboratory methods into the steel mill. An extension of this work will mean almost the remaking of our steel industries. These are the directions for scientific progress in the steel industry.

ELECTRICALLY HEATED SOAKING PITS AND HEATING FURNACES

Discussion by W. G. Kranz

Vice President, The National Malleable Castings Company, Cleveland, Ohio

After reading Mr. Baily's paper on "Electrically Heated Soaking Pits, Reheating and Annealing Furnaces, and Automatic Furnaces for Heat Treatment, as Applied to the Steel Industry," I cannot but feel very much impressed with the author's optimism.

The pioneer in any field always has a hard row to hoe, and in the industrial field especially, as he is always confronted by the question, "What is the relative operating costs between your method and that which is generally used?" and consequently the burden of proof rests with him.

There are very few cases where the fuel cost is in favor of the electrically heated furnace, so that economies in other directions must be looked for, but doubtless it is very true that the electric treating furnace has lower labor cost for operation, less oxidation of the material being treated and by far better and more uniform heat control than any other type, and by reason of these virtues it has a great many advantages where a rigid specification is to be met. But these latter economies are not easily converted into dollars and cents, so it is all the more difficult for the pioneer to drive his arguments home.

I might say that in two of the types of furnaces mentioned in Mr. Baily's paper there has not been a single instance where the failure of the material to pass the specifications was due to the lack of uniformity of treatment.

There is probably one class of heat treatment for which the electrically heated furnace is not the most

economical, and that is for annealing where the heat cycle requires very slow cooling. In this case the combustion furnace can utilize the heat dissipated by the cooling material to support the combustion in the heating portion of the cycle, and the muffle type has many of the advantages of the electric.

With the increasing demand for more economy, better materials and consequently more rigid specifications, the electric heat treating furnace, I feel, has a very bright future; and we all fully realize that the introduction of this type of furnace into the industrial field has spurred every other designer and operator of the combustion furnace on to greater endeavors, which undoubtedly will tend to fulfill a long felt want in the metallurgical field.

President Gary: The next address, on the American Bridge Company's Forge Plant at Gary, Indiana, is by Mr. C. J. Walker, Assistant Manager, Gary, Indiana.

THE AMERICAN BRIDGE COMPANY'S FORGE PLANT AT GARY, INDIANA

CHARLES J. WALKER
Assistant Manager, American Bridge Company, Gary, Indiana.

The American Bridge Company produced its first forgings in 1871 at the Chicago plant. From time to time since that date, plant enlargements have been made. The most important of these enlargements, made necessary by the entrance of our country into the world war, was at the Gary plant. We were called upon to produce rough machined and heat treated forgings for the manufacture of 155 mm. guns, 8-inch railway guns and 240 mm. howitzers. This necessitated the erection of a forge shop, machine shop, heat-treating and annealing shops, chemical and physical laboratories.

Erection of the Ordnance Plant commenced early in December, 1917. Less than three months later, namely, February 1, 1918, the forge building was practically completed, although the winter weather was exceedingly severe, unusually heavy snow storms greatly handicapping the work. In five months, that is in April, 1918, steel work on all buildings was about 80 per cent. completed and fires were burning in some of the heating furnaces in the forge shop. By the end of July, or eight months from start of erection, all buildings were practically completed.

The forge heating equipment, arranged along the west wall of the shop, consists of fifteen 2-door coal-fired furnaces, capable of taking ingots to 78-inch diameter. The coal for the furnaces is conveyed to the hoppers by a Robbins conveyor, and is fed to the furnaces by means of American underfeed stokers. Waste gas from the furnaces passes through Wickes waste heat boilers, which generate steam for the presses.

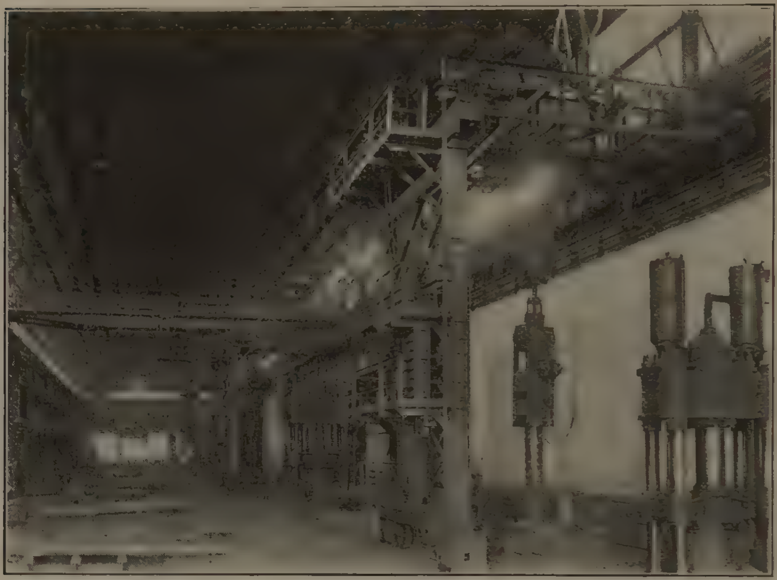


Figure 1—Showing Steam Hydraulic Press Equipment

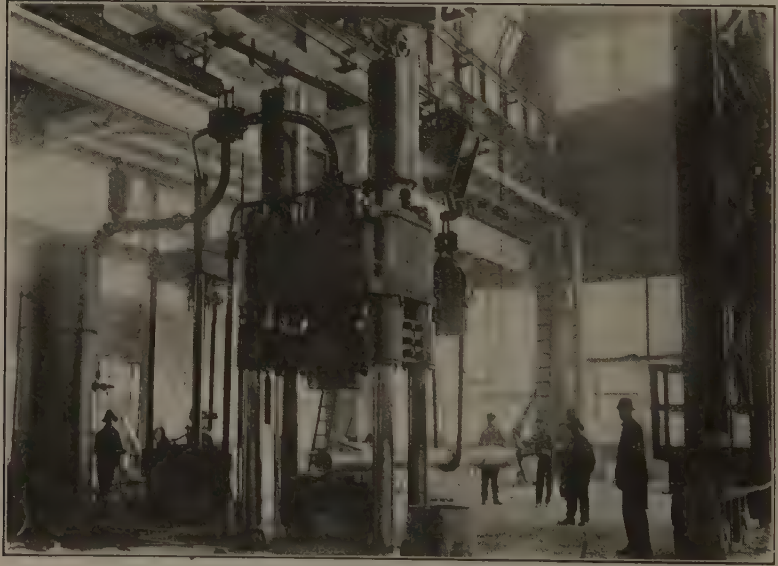


Figure 2—Forging a 155 mm. Gun Tube

The steam hydraulic press equipment (Fig. 1), consisting of one 1,000-ton, two 2,000-ton and one 3,000-ton United Engineering high speed machines, is arranged along the east wall of the shop, each press being served by a single-leg electrically operated gantry complete with electric turning gear, running over-top. Three electric cranes of 80-foot span operate above the gantries. The maximum weight of forging which may be handled is 75 tons. Gun forgings were made from electric nickel steel obtained from the South Chicago Works of the Illinois Steel Company. The smaller forgings were made from blooms, while the larger ones were made from ingots which were received hot from the mill. Ingots were kept hot during transportation by means of special sand and asbestos-lined cars. Upon arrival at the forge plant, the ingots were immediately charged into the heating furnaces.

The initial forging operation was performed on the 1,000-ton press April 24, 1918. The first gun forging consisting of one 155 mm. tube was made May 6, 1918 (Fig. 2). The first of the 2,000-ton presses was placed in service May 15, 1918. The 3,000-ton press is an improved design for machines of this rating.

The machine tool equipment (Fig. 3) of the three machine shops consists of 33 turning lathes, 38 boring lathes, 18 planers, 2 slotters, 8 horizontal core drills, 5 test bar grinders, two 62-inch and one 90-inch cold saws, and a miscellaneous tool room equipment. The initial machine operations on gun tubes, after centering, is turning. The forging is turned to about one-half inch above finishing size and is then placed in the boring lathes. The boring operation was performed by female operators in a very satisfactory manner (Fig. 4). It may seem that the employment of women on such heavy work is unreasonable, but the truth is there is little physical effort required on the part of the operator. The job is set up in the boring machine by a labor gang, the woman starts her machine and must then simply give close attention to the work in order to immediately stop the machine in case

Figure 3—Showing Machine Tool Equipment

Figure 4—Showing Boring Machine with Female Operator

she detects any signs of distress from the cutters. It has been determined in this operation, that women were much more alert and dependable than men.

The outer surface of the jackets for the 240 mm. howitzer and the 155 mm. gun is made up of curved and planed portions on the same transverse section, and in order to plane these pieces they were mounted between rotating centers on bed planers (Fig. 5).

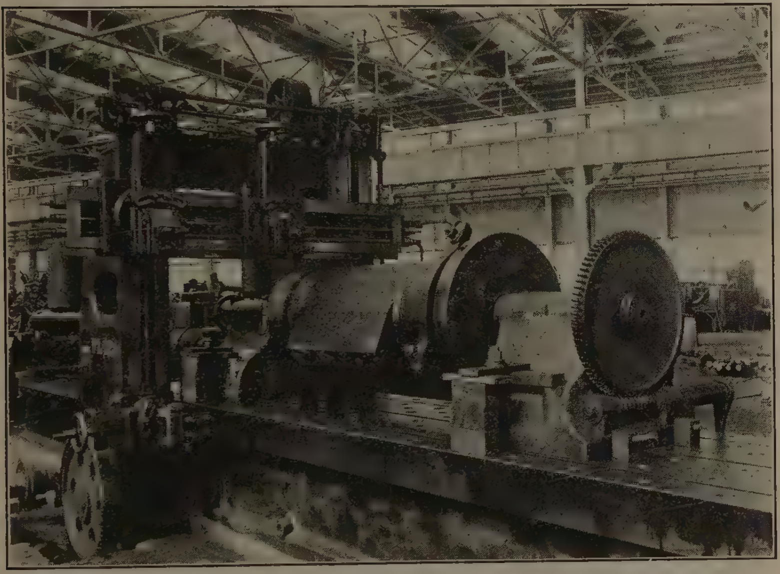


Figure 5—Planing 240 mm. Howitzer Jacket

The heat treating building is served by one 15-ton crane, 40 feet from the floor, and one 50-ton crane, 75 feet from the floor. The heat treating equipment consists of four vertical down-draught oil-fired furnaces, varying in depth from 26 feet to 45 feet, and in diameter 7 feet 10 inches and 9 feet 10 inches, with two quenching tanks, 26 feet deep by 19 feet diameter and 45 feet deep by 16 feet diameter, with a capacity of 120,000 gallons. The first gun forgings were heat treated June 29, 1918. Fig. 6 shows a charge of 240 mm. tubes about to be lowered into the vertical heating furnace. The annealing

and drawing operations were performed in twelve 30-foot oil-fired car bottom furnaces, eight of which may readily

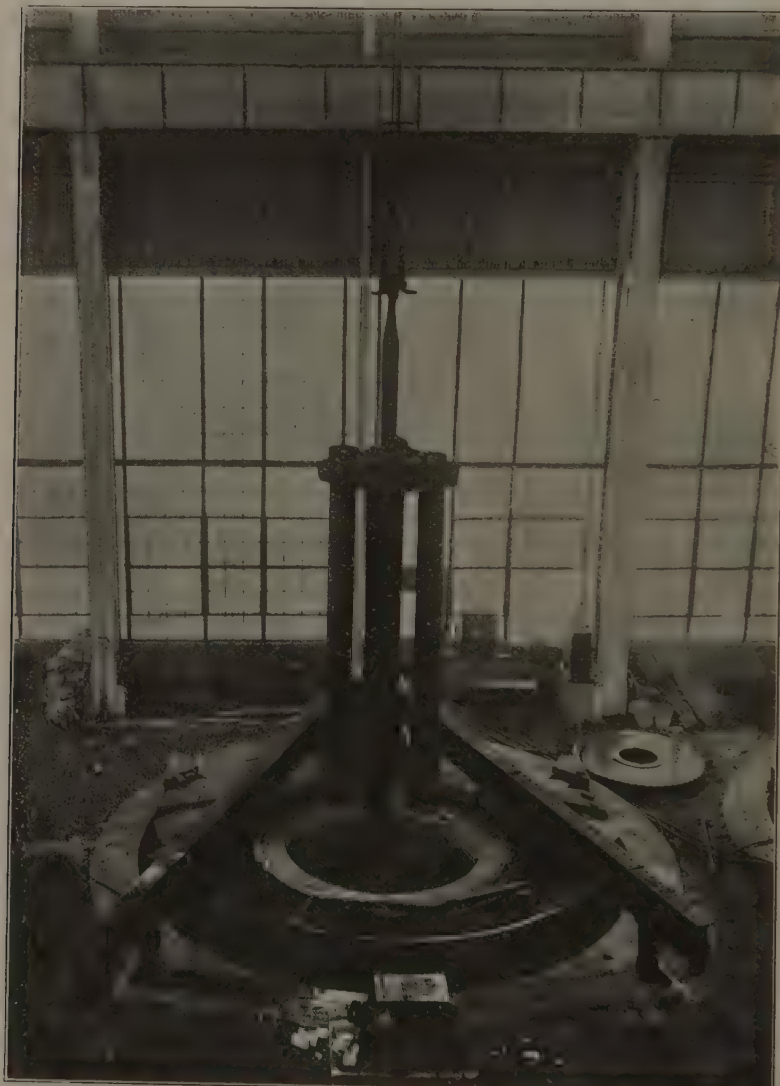


Figure 6—Showing Charge of 240 mm. Gun Tubes about to be lowered into Vertical Heating Furnace

be converted to four 60-foot furnaces. All furnaces were supplied with a complete equipment of Leeds and Northrup recording and indicating pyrometers.

The cutting of test bars from the treated material was done with special tools and equipment, designed and built at the Gary plant, which made possible an average feeding rate of one-half inch per minute.

The special features of this equipment were: a small six-lipped high speed steel cutter attached to a hollow boring bar; and the use of high pressure air and lubricant. The high pressure air admitted to the interior of the hollow bar completely removed all chips, thereby preventing the breakage of cutters and making possible the use of a rapid feed.

Another tool of considerable interest, developed at this plant, is a live-center boring head with which it was possible to remove 700 pounds of chips per hour from a 9-inch diameter hole.

The critical part of the typical boring head is the point of the cutter. This point instead of cutting the metal, actually removes same by scraping. With the live-center head, the metal at the point is removed efficiently by a 3″ drill running at the proper speed. The factor, therefore, which determines the feed to be used in drilling large diameter holes is the removal of the metal at the center. With the live-center drill it is customary to increase the number of cutters in the head, thereby maintaining the work done per cutter at about the same value as with the ordinary head.

After acceptance of test, the test metal portion on each end of the forging was removed by cold sawing and the piece was ready for shipment to the finishing plant.

Fully equipped laboratories made possible complete chemical and microscopical determination.

Since the completion of the Ordnance program it has been found that the plant is admirably arranged and equipped for the manufacturing of various types of hollow and solid forgings rough and finished machined.

President Gary: Gentlemen, when we adjourn we will recess until half past one. When you come back this

afternoon I expect Mr. Schwab will preside. He is unable to remain all of the afternoon. He will probably call to the chair Mr. Topping. We have a very interesting program this afternoon.

The directors of the Institute will meet immediately after adjournment for their luncheon.

The secretary will make an announcement.

THE SECRETARY: The meeting place of the Board of Directors is in the parlor A down the hall, the last of the three parlors. The luncheon to members and their guests will be served in the grand ballroom, which is also on this floor, right across the hall. This evening the banquet will fill all of the floor of the grand ballroom, the space under the galleries, the galleries and the four adjoining rooms.

PRESIDENT GARY: Before next year we probably will have to build a hotel of our own. (Laughter.)

THE SECRETARY: Those who are late with their requests for seats of course understand that there are limitations to the seating arrangements and will have to be happy with the seats that are assigned them. We have done the best we could do with a very difficult problem. However the food will be just the same wherever you are sitting. (Laughter.)

After the dinner, tables will be taken out of the main hall so that those who are seated in the other rooms may move into the main hall, bring their chairs with them, or into the gallery, as may seem best.

There are three spaces reserved for ladies in the gallery, but after the dinner the tables will be taken out of the galleries and any surplus of ladies who cannot be accommodated in the three boxes that were reserved will find space to sit with the gentlemen—they are not afraid; you are all gentlemen and they need not be afraid of you. (Laughter.)

The Chairman announced a recess until half past one.

PRESENT KNOWLEDGE CONCERNING NON-METALLIC IMPURITIES OF STEEL (SONIMS).

Henry D. Hibbard
Consulting Engineer, Plainfield, N. J.

The subject of this paper is now attracting attention of steel metallurgists everywhere because of its bearing on the properties of steels, particularly of those of high quality made for lines of service in which the stresses to be withstood are transverse or tangential as well as longitudinal, such as guns and cylinders for high pressures. Only simple or so-called carbon steels are herein considered.

The National Research Council has instituted a Committee on the Elimination of Sonims in Steel of which the writer is chairman and a number of lines of experiment and observation have already been pointed out to steel makers for them to follow up. Another year should bring forth much information about sonims, some of which, it is hoped, will be of benefit to the man in the shop in aiding him to give his product the highest properties it is capable of possessing.

The name "sonim" is an abbreviation for "solid non-metallic impurities." Other names which have been applied to sonims or some of them are: oxidation products, occluded slag, entrained slag, non-metallic impurities, enclosures, entrained silicates, green markings, mechanically held impurities, and recently and more generally "inclusions," but all fall short of the full requirements of a short distinctive name, so the one devised and used here may be justified. The name "insolubles" would have served fairly well had it been applied when the subject was new.

Occurrence and Composition

Sonims are liable to be particularly plentiful in Bessemer and open-hearth steels and therefore for the

best steels to be made by either of these processes special methods must be employed to clean the steel of them as will be considered later. Crucible and electric steels are less liable to contain many of them.

The genesis of sonims or some of them is perhaps open to dispute, but the following are the writer's present views, to be modified, no doubt, by results of future discoveries and investigations. Those in unfinished and finished steels must be considered separately.

Sonims in finished steel may be classified under the following five cases:

I. The products from the reactions of the manganese and other additions with the sulphides and oxides of the unfinished steel. This is the principal source of sonims.

II. The products from the oxidation of some of the finished steel ingredients by atmospheric oxygen during the progress of the steel from the furnace to solidification in the molds.

III. Oxides from the unfinished steel.

IV. Slag particles entrained particularly from the intimate mixing which results from pouring the charge into the ladle.

V. Particles of dirt and other non-metallic matter such as bricks and clay with which the metal comes in contact during its passage from the furnace to the molds and which are too small for gravitation to send to the top.

Sonims of Case I are a normal product in steels made by the oxidizing processes.

Oxidation by the air in teeming (Case II) is not a great source of sonims as is shown by the fact that finished steel shows a quality which is determined for the most part by its history before teeming, and is not changed greatly by the access of air to it as it passes from the ladle to the mold.

Oxides in finished steel are perhaps uncommon and the reasons for their presence obscure.

Sonims of Cases IV and V even if frequent must be considered accidental. They are prevented or minimized

by physical means or care rather than by metallurgical.

Sonims are insoluble in molten steel. They are either chemically precipitated or they consist of insoluble matter taken up by the metal. Those in finished steel derived from the first two cases are distinguished from the others by the high percentage of manganese they contain.

In unfinished steel, such as the metal of the open-hearth bath, are probably in solution, iron sulphide (FeS) and ferrous oxide (FeO), and in suspension the insoluble and infusible sonims silica (SiO_2) and magnetic oxide of iron (Fe_3O_4). The iron sulphide was in the stock or formed by the absorption of the sulphur from the fuel. The iron oxides were absorbed from those formed by oxidation of the charge in melting as well as those added to the bath in the form of ore. The silica was formed by the oxidation of silicon in the pig iron or other silicon-bearing material in the charge.

When drillings of metal from an unfinished decarburized open-hearth charge are being dissolved in 1.2 sp. gr. nitric acid, close observations will discover streams of minute black particles separating from the dissolving metal. After noting them through a long series of observations in which charges known to be over-oxidized showed more of these particles than others, the writer came to consider them to be iron oxide (Fe_3O_4), their quantity in the solution indicating their proportion in the metal.

Other impurities exist, of course, in solution in unfinished steel, but take no part in the formation of sonims. It is the particular province of the added manganese to deal with the four impurities mentioned and cause them to leave the metal as completely as may be. This reaction may be represented as follows:

In unfinished steel *In finished steel*

$$\left.\begin{array}{ll}\text{In solution} & \left\{\begin{array}{c}FeS\\ FeO\end{array}\right\} \\ \text{In suspension} & \left\{\begin{array}{c}SiO_2\\ Fe_3O_4\end{array}\right\}\end{array}\right\} + Mn \quad \left\{\begin{array}{l}FeS\\ MnS\\ XRO,\ YSiO_2\end{array}\right\} + Mn$$

Some manganese oxide is formed by the added manganese and oxygen in the bath which with FeO form the base for the silicates.

The sonims in unfinished steel are mainly oxides, and in finished steels sulphides and silicates. The silicates are practically always fusible at the temperature of molten steel.

There is nearly always some residual manganese in the metal in the bath remaining unoxidized from that added in the materials of the charge or reduced from the slag by the carbon of the bath. The oxide-eliminating processes therefore proceed automatically while the charge is melted though at a slower rate than after the manganese additions. Therefore, the greater the content of residual manganese the less there is for the final addition to do in the way of cleaning the steel of non-metallics, the less the quantity of final sonims in the steel and the better it behaves when hot worked. When the charge contains from three to five per cent. of manganese there may be little for the final manganese to do, and indeed the steel may be so free from red-shortness as to roll in a way without it.

The sonim-making impurities in unfinished steel which are not in solution are in a state of extreme sub-division and the products of the reaction between them and the manganese are at first in extremely small particles. The reaction with the solid silica and iron oxide particles takes more time than if they were liquid. The silicate particles formed are mostly sub-silicates, fusible at steel-melting temperatures and when they touch each other they coalesce, forming larger particles which in turn join with others and so grow to a size which will rise to the surface if sufficient time is allowed.

It is probable that oxides leave the bath only as silicate and if so enough silica must be present in the unfinished steel to form them. Oxides of iron and manganese are probably not able to leave the metal as such because they are infusible though they may be reduced by carbon to

the metallic form provided there is enough of that element and enough time is allowed.

Dr. Andrew McCance in an extremely valuable paper on inclusions read before the Iron & Steel Institute of Great Britain last year shows that some sonims or inclusions are too small to rise to the top in the time that may be allowed, while larger ones will do so.

Sonims are found sometimes in masses of ounces in weight in the upper central part of large ingots. A boiler plate ingot of effervescing basic open-hearth steel weighing two tons had at the bottom of its pipe (an unusual thing in such steel) a glassy sonim of perhaps a quarter of a pound in weight. It was transparent in thin sections and colorless except for a gray tinge, and it contained bubbles. Its composition was SiO_2 37.06 per cent., FeO 2.16 per cent., Al_2O_3 26.0 per cent., MnO 33.17 per cent. and CaO 1.53 per cent. The alumina was from the aluminum added in the ladle to control the effervescence of the steel in the molds. The presence of the pipe indicates that too much aluminum was added as such steel is not desired to pipe.

When steel infested with sonims is cast into an ingot mold the part in contact with the mold and bottom plate or stool is the first to solidify and will have sonim globules about as numerous as the metal has when cast. The sonims rise through the molten metal, the larger ones with more rapid motion until caught and held by the freezing metal. If the steel is but partly killed and has gas holes in the upper part, buttons of sonims are likely to be found within the gas holes large enough to furnish a sample for analysis. (Fig. 5.) In Bessemer rail steel they have been noticed of a greenish yellow color with a shiny surface like glass.

Scum on Ingots

On low carbon steel, which is made to effervesce in the molds through the liberation of a myriad of gas bubbles, a slag-like scum, more fusible than the metal, collects during teeming and freezing. This scum from its composi-

tion is evidently a collection of the sonims of the steel which have been agglomerated by the stirring action due to the effervescence and have risen to the surface through gravitation. It is perhaps the only considerable quantity of sonims readily obtainable and gives us a starting point in their study. On acid steel the scum is usually olive-green or gray and vitreous, though it may be black and crystalline. On basic steel it is black and crystalline. Table I gives analyses of some of the scums. Most if not all of these samples were vitiated by dirt, clay and refractory materials which got into the molds in various ways and were dissolved in the scum, and consequently the silica and alumina are too high and the other ingredients too low.

TABLE I.
ANALYSES OF SCUMS FROM EFFERVESCING INGOT-TOPS.

	Acid Bessemer pipe steel. First Ingot.	Acid open-hearth boiler steel.	Basic open-hearth boiler steel.	Basic open-hearth boiler steel. Open molds	Basic O H boiler steel	Covered
Fe		15.96	15.35	11.65	15.20	16.10
SiO_2	7.95	20.38	17.14	19.70	16.80	24.20
P.	.043		.03		.02	.02
Mn	38.66	48.50	36.00	40.36	37.57	30.70
Al_2O_3		4.00	15.08		3.05	13.50
S.	2.51	.39			.06	.10
CaO					5.04	1.20
Mg.O					1.80	
TiO_2					*5.50	.60

* This TiO_2 came from the addition of 2½ lbs. of ferrotitanium to the ton of steel.

That the scum comes chiefly from the metal (Case I) and is not made to a large extent by the oxygen of the air uniting with the molten metal (Case II) has been proven by experiments in which the circulation of the air in the mold has been prevented by covers, the quantity and composition of the scum being but moderately changed by the free access of air during teeming and freezing. The air in the molds was displaced by gas from the metal which escaped and burned around the edges of the covers.

Manganese Sulphide

This sonim is formed by the reaction between the added manganese and a part of the iron sulphide. It is insoluble in the metal and is not miscible in the silicate sonims though it sometimes attaches itself to a silicate mass as has been observed by several investigators. In the ordinary qualities of steel its effect is practically negligible.

That all the sulphur is not converted into manganese sulphide is shown by the fact pointed out by Stead that sulphur segregates strongly in finished steel while manganese does not. The slight segregation of manganese sometimes found comes probably from the collection of sonims containing that element in the upper part of the ingot.

Silica

Silica is an important and perhaps necessary constituent of sonims of Cases I and II. It is formed of the silicon contained in the pig iron of the charge in the Bessemer and open-hearth processes which is oxidized in melting and during decarburization.

It is doubtful if silicon or silicide of iron exists as such in the metal of a bath which has been boiled briskly for an hour or more with ore, but that all present in the metal is oxidized.

Most of the silica so formed goes quickly into the slag, but some remains entrained in the metal in a swarm of particles so small as to be unaffected by gravitation much as a little clay mixed with much water will remain for a time suspended in the water, making it roily.

Due partly perhaps to mass action the silica and oxides of iron in the metal do not freely or at least completely combine to form silicates which might be fusible and so escape, but they remain in part at least in the metal until the addition of manganese whose oxide fluxes them.

What the chemist reports as silicon (Si) in steel is pretty sure to exist in the finished Bessemer or open-

hearth steel in part at least as a silicate of iron and manganese, and if it is low carbon steel to which no silicon has been added at the end practically all the silicon may be in that form. Thus 0.01 per cent. of silicon may represent 0.10 per cent. of subsilicate $3RO, SiO_2$ which having a specific gravity about half that of iron would represent sonims of 0.2 per cent. volume of the steel. This amount or even less when existing in certain ways considered elsewhere may account for almost any degree of poor quality in the steel.

Alumina

Aluminum is often added to simple steels and its oxide Al_2O_3) has been found in steels as sonims by Sauveur, Comstock, Brearley and others, and it occurs also as an ingredient of silicate sonims. The oxide though infusible at the temperature of molten steel nevertheless has some power to coalesce into larger masses due probably to the presence of fusible silicates which act as a binder to hold the infusible oxide particles together. These oxide sonims of alumina are not elongated by hot-working as are silicate sonims probably because the alumina at the temperature of working between 1,000° and 1,200° C. is stronger and harder than the lead-like metal which flows around it like wax about a grain of sand imbedded in it.

Bessemer Process

Bessemer steel as usually made and cast into ingots for rolling is likely to contain myriads of sonims usually of globular form. Such steel is made in the ladle by the addition of a manganese alloy to the blown iron and the reactions of the added manganese with the oxides of the blown iron produce silicate particles throughout the mass of the metal as in Case I. In the limited time which elapses before the steel is teemed into the molds these particles make some progress in coalescing into visible drops which is further advanced by the agitation resulting from teeming. In the molds the metal first to freeze

on the bottom and sides will contain sonims as numerous as the steel when teemed, but in the time which elapses they float out to some extent, so that in the central portions they may be but a fraction as numerous as near the skin of the ingot.

Acid Bessemer rail steel ingots cut up into slices for examination at Watertown Arsenal some years ago showed uncountable myriads of sonim globules within 1 inch of the bottom of the ingot while 6 inches from the bottom where the steel had remained liquid about 15 minutes longer they were not over one-fifth as numerous. The remaining globules in the central portions of the ingot of which many hundreds were counted on a quarter section of the ingot varied in diameter from .03 inch down. The larger of these at least were on their way to the top when caught and held by the freezing metal.

Evidently this ingot contained over 10,000,000 sonim globules large enough to see with a strong magnifying glass and uncountable myriads of smaller ones, weighing probably between one and two pounds in all.

One Bessemer rail plant improved the quality of its rails greatly by adding molten spiegel to the blown charge in the converter and holding for 2½ minutes when it was poured into the ladle and then teemed.

Acid Bessemer steel for castings may, however, be treated so as to contain but a moderate number of sonims. It may be blown hotter and then held in the ladle after the final additions so that the great bulk of the sonims will escape to the slag. Holding a two-ton heat in the ladle eight minutes has been found very efficacious in ridding steel of sonims and giving it good physical properties, particularly good elongation and contraction of area which were not attained when the steel was teemed immediately after the manganese addition.

Another way which has been found efficient in making castings: make the final additions in the converter, and hold it there before pouring it into the ladle, the length of time varying with the size of the heat.

Figs. 1 to 5 illustrate the occurrence of sonims in one of the Watertown ingots. From Tests of Metals of 1909.

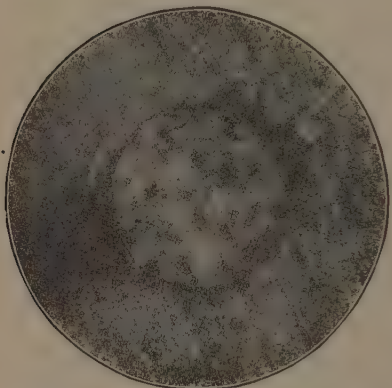


Fig. 1 shows a large sonim globule about .02 inch in diameter

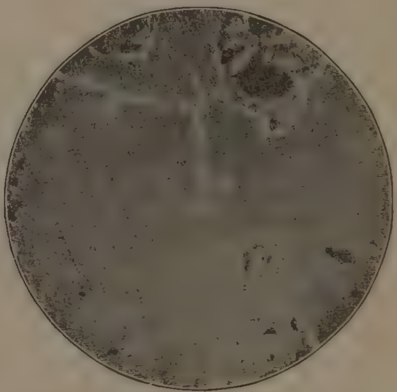


Fig. 2 shows several which were but .01 inch or .02 inch apart

Fig. 3 shows a quarter section of the ingot in which 1,053 sonims were counted, ranging from .01 inch to .03 inch in diameter

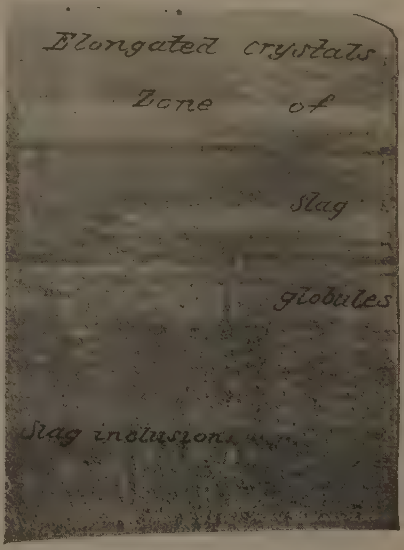


Fig. 4 shows a quarter section of the ingot having a zone of sonim globules around the outside with large sonim masses in the interior

Acid Open-Hearth Process

In this process a cold charge when first melted will contain the usual oxides of unfinished steel and will have a slag which contains oxide of iron uncombined with silica, which oxide reacts with the carbon of the metal, forming carbonic oxide. The slag, however, through loss of this

Fig. 5 shows a section from the upper part of the ingot containing gas holes, 9 of which contained buttons of sonims referred to. Indicated by arrows.

oxide of iron and the addition of silica from the bottom, steadily becomes more acid and its power to oxidize the carbon diminishes in proportion as seen by the gradual lessening of the boil in vigor. Fresh additions of ore are required if more carbon must be eliminated from the metal.

The acid slag absorbs the oxides it touches and thereby favors the elimination of sonims and the charge may be held indefinitely to allow the oxides of iron and silicon in the metal to be taken up by it or the oxides of iron to be reduced in part at least by the carbon present. When the

carbon is high as in spring steel the metal may be cleaned of iron oxides almost completely in time. Whether or not suspended silica is reduced by the same treatment is unknown, but probably it is, as some observers have found unfinished acid steel to take up silicon when held in the furnace, resembling in that feature crucible steel, though to a lesser degree.

The residual manganese until all oxidized, as it sometimes is, keeps eliminating oxides from the unfinished steel as previously stated, but no manganese is reduced from the slag (so far as the writer has found) which might keep up the purifying action, though, of course, it can be added from time to time when an exceptionally pure steel is desired.

Basic Open-Hearth Process

In the basic open-hearth process the slag always contains free oxide of iron uncombined with silica and this oxide keeps entering the metal either in solution or suspension. The slag also contains free oxide of manganese associated with the oxide of iron which in part accompanies the latter into the metal. These oxides are continually being reduced by the carbon in the metal, the carbon itself being oxidized to carbonic oxide which rises to the surface in bubbles causing the "boil." The iron and manganese reduced enter the metal. The more manganese in the slag the better, at least up to 15 or 20 per cent., as the more manganese will enter the metal and flux the oxides of iron and silicon, and so eliminate them, leaving less for the final addition to do. The latter may be proportionately diminished in quantity without injury to the quality of the finished steel.

An addition of ore has greater effect on the charge than in the acid process where a part of the ore is soon combined with silica and only the remainder is useful in oxidizing carbon.

Crucible Process

The crucible process is particularly favorable for the production of steel free from sonims, to which fact its suitability for cutting tools is no doubt due in part at least. It is an acid process and no oxides are absorbed from the strongly acid slag, but on the contrary the slag sticks to and absorbs any of the oxides which touch it and which might form sonims if left in the steel. Of course, some oxide of iron is adhering to the materials used and some entrained slag exists in the wrought iron of the charge, and these enter the steel as it is melted, but the quantity of steel is small, the distance to be traversed to meet the slag short, and there is some stirring effected by the bubbling from the escape of the gases before the steel is killed, which brings all parts of the charge into contact with the slag. The time for killing after melting say ½ to ¾ hour is ample for those sonims which are not reduced by the carbon to escape. All these conditions favor clean steel with good "body." Hastening the process by adding a gas solvent such as silicon or aluminum to kill the steel is fraught with some risk lest the shortened time be not enough to permit of the escape of the sonims which may be formed and the quality of the steel may then be inferior.

The slag in this process is viscous and tends to cling to the crucible walls when the steel is teemed, and any that accidentally runs into the mold remains usually in masses or globules large enough to rise to the surface before they are caught by freezing of the metal.

Electric Process

The electric process of refining steel whether melted elsewhere or not is equally as favorable to the elimination of sonims as the crucible process. The metal may be held indefinitely under a non-oxidizing slag with conditions favoring the reduction of the oxides to the metallic state or their incorporation in the slag and the elimination of the sulphur as calcium sulphide. Hence, the steel

if properly treated will as cast be thoroughly cleaned of sonims.

Electric steel is, however, prone to inter-mix with itself sonims of slag if permitted by allowing the steel and slag to run into the ladle together (Case III mentioned above). The strongly basic slag seems to have less surface tension than the strongly acid slag of the crucible and so unable to resist being broken up and intimately mixed with the metal. The sonims formed are retained in the outer parts of the ingots which are first to congeal and there is insufficient time for them to escape. This trouble is avoided by providing in the furnace spout a brick dam which leaves a hole at the bottom of the spout for the steel to run through while the brick holds back the slag. A combustible plug in the hole holds back the slag until the level of the metal is above the hole. Without this precaution the steel is likely to have sonims near the surface which are exposed by hot working and form defects. In wire-drawing sonims have been found to wear and damage the dies excessively and electric steel was condemned for the purpose until the cause was found and the cure applied.

Effects of Sonims

In previous papers the writer has dwelt at some length on the effects of sonims which may be summarized here. It is, of course, evident that any non-metallic substance included in steel must work harm to its properties, but the way in which such substances are distributed within the metal is even more important than their quantity. In unfinished steel it is chiefly the sonims which make the steel redshort and unworkable. In finished steel they may also make steel redshort, though, of course, not to the extent they do in unfinished steel. Their manner of occurrence is the important thing: whether or not they have collected into globules. Fig. 6 shows sonims in their most harmful condition located along the boundary surfaces of the original grains of the ingot.

The sonims of the finished steel when first made are

exceedingly minute, and if the steel be cast immediately many of them are likely to be rejected by the freezing metal as it forms grains and be located between the grains where they break the continuity of the metal and form weak surfaces running through the mass. (Fig. 6.) Thus

Figure 6—Nickel steel x 100. Carbon 0.44 per cent. Showing sonims along the grain boundaries in the most harmful manner.

arranged they tend to make the finished steel redshort and to cut down elongation and contraction in the tensile test. McCance, Brearley and others have found small sonims so located along the boundary surfaces of the original grains of the ingot and though the grains of the steel were changed and refined by heat treatment the insoluble sonims persisted in their original locations. The damage they cause when in this state is ruinous and incurable.

McCance found 90 per cent. of the defective steel he has had to do with in the last five years has been due to the presence in the steel of non-metallic inclusions or sonims.

At one rail plant some years ago, before the importance of sonims was recognized as fully as today, the practice was tried of allowing the steel to stand several minutes in the ladle before teeming, with the result that the percentage of seconds was cut down to a small fraction of what they had previously been. The practice was claimed to interfere with the output, however, and was discontinued.

At another rail plant the practice had been to add the manganese in the furnace before tapping and the failure of a rail in the drop test was a rare thing. The practice was changed to adding manganese in the form of melted spiegel in the ladle with the sequence if not the result that ten per cent. of the rails failed under the same drop test.

These experiences with rails point to the better elimination of sonims in the practice which gave the better results. The point of similarity in the two better cases is the longer time between adding the manganese and casting.

Sonims have usually but slight effect on the tensile strength and yield point of steel, but diminish greatly, sometimes by half, the elongation and contraction of area in the pulling test as shown by Prof. Styri and others. Because of this lack of ductility, the ability to withstand a drop or other impact test is proportionately lessened.

In ordinary cases, as for structural steel, with sufficient hot deformation, that is reduction by rolls, the ductility longitudinally of steel containing many sonims may be increased so that fair elongation may be obtained. In this case the sonims act like the entrained slag in wrought iron, which may with sufficient work be given good longitudinal ductility.

In hot-working steel longitudinally sonims which are fusible, or plastic, or even powdery at the temperature of

the steel will be drawn out into threads or filaments like slag in wrought iron. Strong infusible ones like alumina or silicate of aluminum which may be made stronger by heat, may preserve their shape, as noted. The sonims as drawn out have lessened effect in the one direction even though they constitute presumably the same proportion of the cross-section of the piece.

When low carbon steel, which would effervesce in the molds if allowed to do so, is killed by the addition of silicon or aluminum in the furnace, ladle, or mold, no scum rises and the sonims are kept within the mass of the steel.

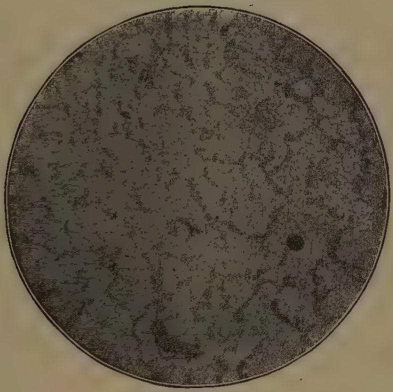


Fig. 7.

What effect they have there is unknown, but it seems plausible to hold that their effects are the same as in other steels. If steel is to be killed, then to get the best properties it should be cleaned of sonims as completely as practicable before the addition of the killing ingredients as the collection of sonims into floatable masses proceeds very slowly in dead steel.

In structural castings a few globular sonims are quite negligible, their effect being only the small loss of strength and ductility due to their cross-sectional area. Fig. 7 shows such a sonim in cast steel.

Elimination of Sonims

To make dead steel as clean of sonims as practicable the things to be observed are:

1. Have the unfinished steel as free from oxides as possible at the end to diminish the work for the final additions to do and the quantity of sonims to be made, by holding it without ore additions and with ample carbon and manganese in the bath. The manner and rate of boiling and the fracture of a slag sample will tell the furnaceman how his bath is in this respect. The "boil" must not be vigorous for the percentage of carbon in the metal.

2. Time must be allowed to elapse after the addition of the manganese for the sonims to be precipitated, or changed chemically as already noted, then to collect into globules or drops, and then to float to the top. Probably moderate agitation or stirring helps materially this gathering of sonims which "wet" each other into drops of floatable size.

When sulphide sonims touch others of their kind they coalesce, forming larger particles and silicate particles do the same, and with favoring conditions these processes continue until particles or globules are formed large enough to rise.

If the sonims do not coalesce and float it may be that their composition is not right. The basic oxides of iron and manganese by themselves are too infusible to stick together, and so grow and escape. They need combination with silica or some other acid to make them fusible. As sonims are eliminated from steel by their floating up when the heat is held quiet in the ladle there is a nice point involved. If the time has been sufficient to clean the lower layers then teeming may begin and the rising cloud of sonims will have in addition the duration of teeming in which to reach the top. This may be half an hour or even more in some cases. The proverbial ingot butt which always rolls well illustrates this point, even if its compact form does lessen its internal strains and so improves its

rolling qualities. At one works making gun steel the charge is held in the furnace 15 minutes after the first part of the final manganese is added, and 20 minutes in the ladle where it is finished steel.

In steels where the service stresses act in more than one direction as in the guns and cylinders mentioned, the purification from sonims cannot be too complete. So, too, in fine cutting tools and in roller bearings where minute sonims in roller or raceway have been found to start defects which seriously cut down the term of service.

Conclusion

To forecast the effect of sonims on the properties of steel there is much work to be done and interpreted, but it may be said that one must know their quantity, composition and manner of distribution or occurrence in the steel. The quantity and composition must be ascertained by chemical means, and the mode of occurrence, as far as may be, by the microscope.

The experience of McCance and others shows the importance of the subject and the need of further study, investigation and experience to find the answers to the many questions which arise.

Vice-President Schwab: I understand there are some gentlemen here who desire a little time for the discussion of this paper, and I will, therefore, allow five minutes to any gentleman who has anything to say. We will hear first, Mr. John A. Mathews, President, Halcomb Steel Company.

PRESENT KNOWLEDGE CONCERNING NON-METALLIC IMPURITIES OF STEEL (SONIMS)

Discussion by John A. Mathews
President, Halcomb Steel Company, Syracuse, N. Y.

We are indebted to Mr. Hibbard for the comprehensive name which covers a multitude of faults that steel is heir to. The name "sonims" was suggested several years ago, and would have been better known and more generally used had the subject been given more discussion and attention in polite technical society since the time of Mr. Hibbard's proposal. There had been a tendency to shy at this discussion until recent conditions forced it upon our attention, and it is now receiving the belated consideration it deserves.

In the old days, when carbon steels and even the early alloy steels were for the most part used in the natural or annealed condition and the condition of use implied low stresses, chemical analysis and tensile tests proved a quite sufficient criterion of suitability. Now, however, in the era of high speed, high power, light weight and high stresses, a new situation has arisen and metals must be subjected to more careful methods of manufacture and more rigid inspection. The new alloy steels are heat treated to show high physical properties, and the static tests fail to show potential causes of failure. They must be supplemented by microscopic examination, shock and repetitive impact tests, etc. These tests will reveal the weakness and unreliability of "dirty" steel, or steel afflicted with superabundant "sonims," to use Mr. Hibbard's more dignified name.

Every designing engineer knows the danger of sharp angles or notches and attempts to avoid the danger by fillets. The same engineers have not come to recognize

the sonim as an internal notch, and, as Dr. McCance has pointed out, mysterious failure in parts that have not been subjected to unreasonable stresses usually originate in some nucleus consisting of a non-ferrous inclusion or sonim, and the course of failure may frequently be traced through a series of such inclusions. They constitute a source of weakness because they are in fact a break in the continuity of the steel, and hence stresses that would be readily withstood in sound metal are not withstood by unclean steel. I have frequently seen parts that have failed under impact where the nucleus is easily discernible to the eye. In case-hardened parts sonims lead to spalling or pitting, the former where the inclusion is more or less parallel with the case and the latter where it is at right angles.

The Committee on Aircraft Engine Forgings, of which I was chairman, came to the conclusion that so-called "hair lines" were due to sonims, elongated in the direction of rolling or forging. They varied much in length and visibility. Sometimes they were seen only on the ground and polished surface with a magnifying glass. Actual grinding tests and count of hair lines on cylindrical surfaces of chrome nickel steels of the type represented by 3.5 per cent. nickel, 0.75 per cent. chromium and 0.35 per cent. carbon were made. Steels to the same specification were made in the basic open-hearth, acid open-hearth and basic electric furnace. The relative average count was respectively forty-six, twenty-three, and six, and it was further noted that the hair lines were in general much shorter and inconspicuous in the electric product than in either class of open-hearth products.

After our attention was called to this question, we produced many heats of this analysis that were entirely free from the defect. However, in our report to the Aircraft Production Board, we stated that, in our judgment, it was not possible to guarantee any steel perfectly free from them. They might be so infrequent and incon-

spicuous as to escape detection in individual inspection. In these inspections a cylinder was subjected to from six to ten grindings, and the general experience was that the hair lines were most numerous near the surface and tended to decrease or even disappear, even in fairly dirty steel, after six or more grindings. This would seem to confirm Mr Hibbard's idea that these represent the sonims entrapped upon first cooling in contact with the mold. The center of the ingot remained liquid long enough for many of them to escape. The grinding operations were not continued long enough to show whether they recurred at or near the center zone of the cylinder.

The tests referred to confirm Mr. Hibbard's conclusions as to the relative frequence of sonims in different processes of manufacture, and particularly confirm his opinion that the electric process closely approximates the condition obtainable in crucible melting.

VICE-PRESIDENT SCHWAB: Mr. Kelley.

MR. KELLEY: I have had the advantage of most of you in that I have had previously a copy of this paper for the purpose of preparing my notes. I can assure you that it is a very interesting one.

PRESENT KNOWLEDGE CONCERNING NON-METALLIC IMPURITIES OF STEEL (SONIMS)

Discussion by G. L. Kelley
Engineer of Tests, Midvale Steel & Ordnance Company, Nicetown, Pa.

Mr. Hibbard's paper presents an interesting summary of our present knowledge as to the nature and occurrence of solid non-metallic impurities in steel and methods for preventing their appearance in too large amount. Most of us will agree in all chief points with the statement of these facts as presented by Mr. Hibbard.

Dr. A. McCance, in his article on "Balanced Actions in Steel" in "Engineering," November 22, 1918, and Professor Styri, in an article on "Flaky Fractures and Their Possible Elimination," which appeared in "Metallurgical and Chemical Engineering," May 1, 1919, indicate as a consequence of the physico-chemical equilibrium which exists in melting furnaces that a certain amount of oxides in the metal is inevitable. This will constitute a small source of comfort to us in the face of such problems as this paper brings before us. It does not, however, relieve us from the necessity for making an effort to avoid, as far as possible, the production of steel in which these inclusions are large in amount. The alleviation of this condition must take the form of an increase in care in all steps in the manufacture of the steel. The cost of steel will often determine the amount of effort which can be put upon the manufacture. Low price steel must of necessity be manufactured without too great elaboration of the processes, and, accordingly, it will contain larger amounts of these objectionable impurities. With higher grade steels, where the increase in cost incident to greater care in manufacture is not a too serious obstacle, all possible precautions must be observed.

These precautions in open-hearth furnaces will generally lead to the selection of acid furnaces in preference to basic furnaces. They will in all cases lead to the use of a carefully selected charge and to melting under conditions which will require the addition of a minimum amount of finals. The time of holding in the furnace before and after adding finals, the time of holding in the ladle before pouring, the question of top and bottom pouring, preparation of molds and runners, including the selection of proper refractories for the latter, and the rate of pouring, are all self-evident factors which enter into the manufacture of good steel, and which may be counted upon to give results in proportion as they are observed. Under these conditions, steel can be produced in which the presence of solid non-metallic impurities is not a serious detriment, but which in amount are still far from realizing the ideal conditions suggested in the theoretical papers of Dr. McCance and Prof. Styri.

Mr. Hibbard quotes McCance, Brearley and others as having found small sonims located in the boundary surfaces of the original ingots, and adds that after refinement by heat treatment they persisted in their original locations. It is to be expected that they would fail to break up on refining the grain, but, by this refinement, they become so isolated from any fixed structure in the ingot, such as a grain boundary, that their capacity to work damage is greatly reduced.

Vice-President Schwab: Is Mr. Lindemuth here?

PRESENT KNOWLEDGE CONCERNING NON-METALLIC IMPURITIES OF STEEL (SONIMS)

Discussion by L. B. Lindemuth
Consulting Engineer, 40 Wall Street, New York, N. Y.

The interest among steel manufacturers in the subject dealt with in Mr. Hibbard's paper has increased in the past four years from a comparatively few to almost every steel maker in all countries. Forced production of ordnance material, not only in regular established ordnance plants more or less familiar with non-metallic inclusions, but in many plants previously inexperienced and uninitiated into the effects of this serious phase of steel making, has brought it to the attention and thought of nearly every steel metallurgist.

Mr. Hibbard's paper before the Sixth Congress of the International Association for Testing Materials in 1912, as well as previous and subsequent papers presented both in the United States and abroad, attracted attention from steel plants, in general, as a scientific, rather than practical, interest.

The paper presented today, as well as the detailed investigation by Dr. Andrew McCance, presented before the Iron & Steel Institute of Great Britain in 1918, and discussions by Brearly, Stead, Rosenhain, Hatfield and others, and also the recent discussion of the duplex process in the paper, "Modern Steel Metallurgy," presented before the British Iron & Steel Institute on May 8, 1919, are received with an almost universal realization of the practical importance of the subject and the necessity for devising means to eliminate or reduce to a minimum the effect of impurities designated by Mr. Hibbard as sonims.

There is, unfortunately, a factor of this subject which

bears more importance than I believe is generally appreciated, and which, to a certain extent, interferes with a scientific analysis of the subject and must be eliminated, or reach the irreducible minimum, before we can have any assurance whatever that our steel is free from dangerous inclusions. This feature, mentioned by Mr. Hibbard, is the introduction of non-metallic impurities from sources foreign to materials entering into the metallurgical reactions. These sources would include brick, silica, sand, ganister, loam, fire clay, furnace bottom material, dirt from the molds and stools, mold wash or non-metallic ingredients from any other similar source. The composition of such impurities consists of silica, oxides and silicates of aluminum, iron, manganese, lime and magnesia, and all manner of complex silicates of any one or combinations of all. These silicates, in turn, are capable of combining with sonims produced by reactions in the steel. With such combinations it is difficult, or I might say impossible, to determine which or how much of these non-metallic impurities are produced by materials used for the metallurgical reactions or by materials coming from outside sources.

There is much evidence which shows that materials from outside sources are present in steel in more or less large amounts. A rough average of the life of a ladle lining indicates that the equivalent of 0.3% of the weight of the heat in brick work is removed from the ladle lining each time a heat is tapped into it. For a 100-ton heat 672 lbs. of brickwork and clay enters into the steel and slag. No doubt a large portion of this enters the slag, but further evidence shows that some of it is caught in the steel.

It is the practice in some plants to use sand around the nozzle to prevent a leak while tapping. This sand, or a large portion of it, is washed into the first part of the heat while the steel is being poured. The nozzle and sleeve bricks wear away appreciably, both by fusion and abrasion, and these particles are necessarily churned up

with the steel in pouring. Where steel is poured through boxes or tun dishes, the same action of fusion and abrasion takes place with the lining and nozzles of the boxes. As slag is not present in the box, it necessarily follows that the brick and clay enter the molds with the steel. Similarly, in bottom pouring, where steel passes through firebrick runners and enters the bottom of the molds, the runners are fused or abraided and the particles of fused clay must pass into the mold from the bottom. The advantage of good surface conditions gained by this method of pouring is possibly offset by the liability of a greater number of inclusions. This would seem particularly true where comparatively long ingots are cast. Some plants, in bottom pouring, have produced steel for ordnance exceptionally free from sonims by the proper selection of runner bricks, careful temperature control, rate of pouring and possibly by a mold designed to prevent corner weaknesses which are sometimes associated with sonims, and by a comparatively short ingot. The advisability of top or bottom pouring, and the conditions which would require one or the other for producing steel more free from sonims is still undetermined. A general rule applicable to one plant cannot necessarily be applied to others until further observations develop some definite knowledge about this much disputed subject. It is common practice in many plants where ingots are top poured to wash the stools with a clay or lime wash. That stools are worn away by the force of metal striking them is further indication that whatever material was used for this wash will, in part, be mixed up with steel in the molds. It is further common practice to wash molds with a mixture of graphite and water or graphite and molasses or tar, or some other binding substances. The graphite commonly employed contains about 50% ash which is an iron aluminum silicate. When fused under reducing or neutral conditions this ash is green and crystalline, similar to inclusions which I have often seen, and its position in the molds is particularly favorable for

its entanglement near the surface of the ingot. Furnace slag may be introduced into the steel by having slag from the previous heat adhering to the sides and bottom of the ladle. As the entire surface of the ladle is more or less fused away, this furnace slag will of course be similarly fused. The fusion or abrasion of furnace runner brick, ganister and clay, and loam if used, in the runners, the abrasion of furnace bottom, particularly where bottoms have been built up from lime and previous slags, rusty molds and stools, asbestos packing, etc., can be other possible sources for the introduction of oxides and silicates into the steel. It is problematical what proportion of impurities so introduced will float to the surface and also what conditions will best promote this floating.

It is generally conceded by all investigators, and practical results bear out the contention, that in the manufacture of steel an appreciable percentage of residual manganese throughout the making of the heat is of the greatest benefit in reducing sonims, which I might designate as being of metallurgical origin, and producing steel with the best rolling or forging qualities.

If we were to overlook the fact that non-metallic inclusions can occur from the sources outside of the steel which I have just enumerated, then the general assumption that steel should be poured hot for the elimination of sonims would probably be correct, but the fusion of bricks, abrasion of furnace bottom and cutting of stools and perhaps molds is increased by an increasing temperature so that by choosing conditions which will better one side of the equation we have produced an effect which increases the tendency for inclusions from another source. It might be of advantage to have the steel in the furnace, at some stage of the process, above normal temperature, but allow it to cool in the furnace before tapping.

Outside of the question of inclusions, the question of pouring steel at a temperature above normal increases the difficulties encountered from crystallization known

under the general term of "ingotism." To recommend pouring steel at higher temperatures, without the knowledge of the proportion of sonims introduced from outside sources, and without considering ingotism, might lead to the elimination of one class of impurities but reduce the quality of the steel by introducing other defects just as harmful, from a source caused by the high temperature. I think it will be conceded that generally the best results are obtained by pouring steel on the cool side rather than the reverse.

Fused fire brick or fire clay and unfused grains of silica sand are trapped and held in steel even under conditions which we would think would be most favorable to their floating to the top, namely, in skulls from the bottom of ladles. Here solidification takes place slowly compared to solidification in molds, but I have seen in many of these ladle skulls, several inches from the surface, grains of unfused sand, light bottle-green slags, transparent amber-color slags, dark-green opaque slags, and portions of fused bricks from the ladle lining either embedded in the solid steel or entangled in fir-tree crystals.

The flash or fir from the bottom of an ingot, which freezes instantly, often shows an inclusion of fused material of considerable size.

In another investigation I had analyzed, from ingots of acid open-hearth gun steel, slags which collected on the outside surface of ingots about one-third the distance from the bottom and also from the same ingots slag which had collected on the top. The average of these slags analyzed as follows:

	Slag 1-3 from Bottom *Dark Greenish, Tansparent*	*Slag from Top Surface* *Bottle Green, Transparent*
SiO	56.38	49.35
FeO	6.78	4.75
MnO	17.72	29.59
Al_2O_3	15.33	12.89
CaO	1.39	0.89
MgO	1.90	2.28

To these heats no aluminum was added either in the

ladle or molds. The increase in manganese oxide from 17.72% to 29.59% substantiates the statement that silicates will react with the manganese of the steel, and the alumina indicates that these slags were of clay origin. I am unable to account for the presence of lime and magnesia unless it could come from slag left in a ladle which had previously been used for basic steel. In other cases of large forging ingots from 30″ to 40″ in diameter, grains of sand, bottle green, transparent inclusions and blue-green aluminum silicates have been encountered in comparatively large sizes, 8″ to 10″ from the surface of the ingot and located anywhere in the bottom half of the ingot.

Whether or not agitation of the metal helps remove sonims is also a question which is problematical. It is reasonable to expect that if we find inclusions in all parts of ingots of a size visible to the naked eye, which should be the ones most likely to float to the top, microscopic inclusions and those of molecular size can exist to an even greater extent under the same conditions. If such is the case, agitation such as occurs in "rimmed" steel, or as is designated by Mr. Hibbard "effervescing" steel, would tend to keep these small particles in circulation and therefore prevent their rising to the surface. It is also questionable whether quiet or dead steel solidifies more quickly than rimmed steel. Our knowledge on the subject would indicate that rimmed steel would solidify more quickly than dead steel and that solidification takes place very rapidly after the rimming has ceased. If such is the case the sonims which have been circulating by the rimming action would be more quickly caught in the freezing steel than if the steel had quietly solidified. There has recently come to my attention hundreds of tons of soft basic open-hearth "rimmed" steel, bottom poured, which contained enormous quantities of inclusions of large sizes analyzing from 52.0 to 60.0% SiO_2, 5.0 to 7.0% FeO, 2.0 to 7.0% MnO and over 20.0% Al_2O_3. Some of these inclusions showed the unaltered

structure of fused fire brick or clay. On the other hand, in the case of dead steel the growth of the fir-tree crystals with their network of branches would tend to catch such particles as would ordinarily rise to the surface if their progress was uninterrupted. These fir-tree crystals, sometimes 12 inches or more in length, extend into the molten steel and undoubtedly form a serious obstacle to the floating of sonims. The corners of ingots afford numerous examples of non-metallic particles being so entrapped.

Mr. Hibbard's statement that scum collects on the top of rimmed steel but does not collect on the top of dead steel does not always hold true. Manufacturers of rails and other dead steels, whose practice is to make ingots with convex tops, realize that this cannot be accomplished unless particles of slag or scum which have collected on the top are immediately removed. It is true that in many cases this scum does not appear on the top surface of the ingot when making dead steel, but it is almost invariably found in the pipe cavity, showing that it has floated to the top of the liquid metal after the top surface has solidified.

Whether or not there is a larger collection of sonims on the top of "rimmed" steel or dead steel is very questionable, although from general observation I would say that the quantity of scum visible on the top of rimmed steel is greater than that which is encountered in the pipe cavity and on the top of dead steel.

The crucible process is usually credited with producing steel freer from sonims than any other process, but is this to be attributed to the process or to comparatively small heats and almost invariably small ingots? The ingot size, I am sure, has a very pronounced influence on the quantity and size of sonims which can be found, whether of internal or foreign origin.

Crucible ingots of the size ordinarily cast for tools are so small that they solidify clear through almost immediately after they are cast, thus preventing sonims

of molecular sizes from agglomerating and at the same time making their distribution throughout the ingot practically uniform.

If we were to cast an ingot of say 30″ in diameter from crucible steel at the same temperature and under the same conditions as open-hearth steel, I am not sure but that sonims would be as numerous as are sometimes found in steel made by other processes. There is not sufficient information to say whether the practice of the crucible process should be imitated as much as possible for the reduction of sonims.

If it is possible to reduce sonims to a minimum by furnace practice, would not the investigations of Mr. Hibbard and Dr. McCance indicate that the processes most suitable for the elimination of sonims, not considering the crucible process, are the duplex processes using a basic open-hearth furnace and electric, using duplex metal or a charge of 100% scrap. If in the duplex process, using a basic open-hearth furnace, the steel were treated with sufficient manganese to maintain in the charge at all times an appreciable percentage, say .25% of manganese, the sonims should be in a condition to float most readily, the quantity being small on account of the absence of silica or silicon and the distance for the sonims to float to the top being at a maximum 30 inches. The same conditions would exist in an electric furnace where pig iron was not used in the charge and hence no silicon introduced. Manganese in the bath would at all times be sufficient to react on the sonims and to reduce FeO in solution which would otherwise tend to form sonims during solidification. If the steel in the furnace could thus be cleared of sonims to the minimum extent practicable, a comparative measure of sonims rising from foreign sources might then be made. The converse is also true; that is, if we reduce the sources of foreign impurities to a minimum, we could then be in a position to study the quantitive effects of various processes, casting temperatures, etc.

It is almost universal practice to use in ladle linings

and runners, bricks of third quality with regard to fusion temperature. Bricks of this quality are dense and become vitrified and therefore make it easy for the removal of steel skulls and scrap from the ladles and runners. First quality fire clay bricks, steam pressed, have a density probably equal to those of third quality bricks, and it might therefore be advantageous to line ladles and runners with first quality bricks, using a clay bond of equal quality. Loam clay, which is so frequently used in many plants, is much more fusable and more easily washed away than the third quality bricks and therefore is a probable source of more non-metallic inclusions than the bricks, in plants where it is so used.

In this brief discussion I have merely tried to emphasize one phase of sonims which, to my mind, has not been sufficiently brought out by those who have made a study of the subject, and also to point to the exceedingly complex nature of the problem and the comprehensive nature of observation necessary for arriving at conclusions which will be of practical value.

Vice-President Schwab: Mr. Frank B. Poto, I believe, is not here, but Mr. Unger of Cleveland, will read his discussion for him.

Mr. Unger: Mr. Chairman and gentlemen: This is just a few minutes written discussion by Mr. Poto.

PRESENT KNOWLEDGE CONCERNING NON-METALLIC IMPURITIES OF STEEL (SONIMS)

Discussion by Frank B. Poto,
Chief Chemist and Metallurgist, Otis Steel Company, Cleveland, Ohio

In several experiments undertaken to determine the source of the ingot scum on bottom cast basic and acid open-hearth ingots, many analyses were made of the ingot scum.

In some cases the molds were covered by a plate, and in some, uncovered. In all analyses, the high content of manganese was noticeable, and there was little difference in composition between the ingot scum from the covered and uncovered molds.

This should bear out Mr. Hibbard's contention that sonims are mostly the products of the reactions of the manganese with the oxides and sulphides of the unfinished steel.

In my experience, the addition of ferro-manganese to the furnace bath instead of to the ladle has always been followed by a marked improvement in the quality of the steel, provided the heat was held in the furnace long enough for the purifying reactions of the manganese with the oxides to take place.

No doubt this improvement is due largely to a more complete elimination of sonims and sonim-producing compounds, by reduction of the oxides and fluxing of the silicates. That this is largely the case is proven by the great loss of manganese (especially when the ferro-manganese is added to the bath) in a poorly worked heat, and by the comparatively small loss when the heat is properly worked.

As a further means of eliminating sonims, I have in mind a process which is being used to produce a deoxi-

dized basic open-hearth bath. This simply consists in thickening up the slag (starting about an hour before ready to tap) by the gradual addition of burnt dolomite or magnesite.

By such a procedure the normal basic slag is diluted by a non-oxidizing base, lime and magnesia, and it soon becomes very viscous.

In its struggle to attain fluidity, the slag will seize and hold any fluidity agents, such as the oxides and silicates of the bath.

As the metal is covered by a layer of slag, the only source of supply is the bath itself, and it gradually gives up these impurities as the metal comes in contact with the slag.

This viscous slag seems to have a great affinity, probably physical for the oxides, and chemical for the silicates. Ferro-manganese may be added to a bath treated by such slag, and held ten to fifteen minutes before tapping, and there will be little loss of manganese. This would largely eliminate the sonims of Mr. Hibbard's Classes I and III.

Vice-President Schwab: I am sure the paper will reflect great credit upon the author's discoveries and his statement of them, and will well warrant the attention of those who want to read it at their leisure with greater care. The discussions are also very interesting. (Applause.)

We will now have a paper on the By-Product-Coke Plant at Clairton, Pennsylvania, by Mr. Frank F. Marquard, Superintendent, Clairton, Pa.

THE BY-PRODUCT COKE PLANT AT CLAIRTON, PENNSYLVANIA

Frank F. Marquard
Superintendent, By-Product Coke Plant, Carnegie Steel Co., Clairton, Pa.

The Clairton By-Product Coke Plant, without exaggeration, stands today as the climax in the development of the by-product coke oven industry of the world. It is the most comprehensive in plan of operation, the largest in size and in detail of construction the most complete.

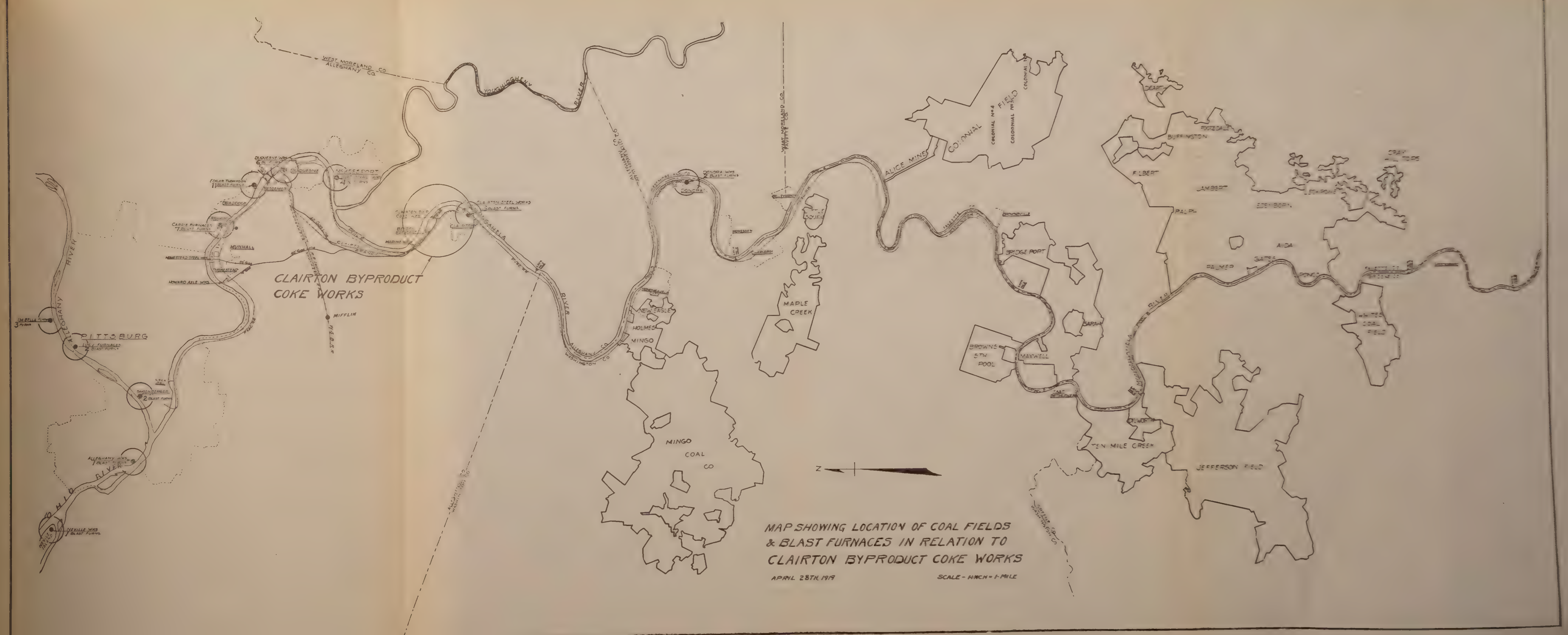
By-Productive vs. Beehive.

The delayed recognition of the merits of the by-product coke oven industry has resulted in enormous waste. In the past twenty-five years, in this country, the beehive ovens have wasted in tar and gas, reduced to coal equivalent, an amount equal to over 300,000,000 tons of coal, and a waste of over four hundred million dollars ($400,000,000) worth of ammonia, and over five hundred million dollars ($500,000,000) worth of benzol products, these conservative amounts being based in each case on sub-normal prices.

The beehive oven is primitive, crude, wasteful, and, in the light of the present-day experience in the operation of by-product ovens, the beehive oven will soon play a very minor part in the coke production of the country.

In the past few years there has been a wonderful awakening. The construction of by-product ovens has been greatly extended. Their merit as an essential industry in time of war, as well as peace, is now recognized by our Government as of national, as well as of economic interest in the development of the iron and steel industry.

In 1918 fifty-six million (56,478,372) tons of coke were produced in this country—twenty-six millions by by-product ovens and thirty millions by beehive ovens;



WEST MORELAND CO
ALLEGHANY CO
YOUGHIOGHENY RIVER
CLAIRTON BYPRODUCT COKE WORKS
MUNHALL
MIFFLIN
ALLEGHANY RIVER
PITTSBURG
OHIO RIVER
ALICE MINES
COLONIAL FIELD
MAPLE CREEK
NEW EAGLE
HOLMES
MINGO
WASHINGTON CO
MINGO COAL CO
BRIDGE PORT
BROWNS 5TH POOL
MAXWELL
TEN MILE CREEK
JEFFERSON FIELD
FILBERT
BUFFINGTON
LAMBERT
RALPH
EDENBORN
AIDA
PALMER
GATES
WHITES COAL FIELD
Z
MAP SHOWING LOCATION OF COAL FIELDS & BLAST FURNACES IN RELATION TO CLAIRTON BYPRODUCT COKE WORKS
APRIL 28TH 1919
SCALE - 1 INCH = 1 MILE

and this year, 1919, will mark the turning point in favor of the production of by-product coke.

In planning the construction and operation of this large plant, three important questions were very carefully considered:

Location, so as to effect maximum economy in transportation of coal, gas and coke.

Type of oven and recovery apparatus most effective for the production of the best metallurgical coke from the coking of 100% high volatile coal.

Market for the coke, tar, gas, ammonia, benzol, coke dust and domestic coke.

As to location, we have been extremely fortunate in having a site located north and adjacent to the Clairton steel plant of the Carnegie Steel Company. This site is 5200 feet long and 1800 feet wide, lying along the western shore of the Monongahela River, 20 miles south of Pittsburgh, and large enough for the construction of 24 batteries of 64 ovens to the battery.

Twelve batteries, 768 ovens, are completed, with a daily coal consumption of 12,500 net tons of coal per 24 hours.

DAILY PRODUCTION AND YIELD FROM 12,500 N. T. KLONDIKE (FAYETTE COUNTY) COAL PER 24 HOURS

Daily Production	*Per Cent Yield—Based on Coal Charged*
8,000 N. T. of dry screened furnace coke (2½% H_2O)	62%
520 N. T. small size coke (domestic coke)	4.2%
900 N. T. coke dust	7.2%
150,000 gals. coal tar	12 gals. per N. T. coal
162 N. T. sulphate of ammonia	25 lbs. " "
29,000 gals. pure benzol	2.3 gals. " "
7,400 gals. pure toluol	.57 gals. " "
2,800 gals. crude light solvents	.22 gals. " "
1,400 gals. crude heavy solvents	.11 gals. " "
75,000,000 cu. ft. surplus gas (575 B.T.U.)	6000 cu. ft. " "

For more recent results, see Table A, below.

In order to handle these large quantities of coal and coke, we found it necessary to construct a river fleet of 120 barges and 7 tow-boats to transport our coal from the mines to the ovens; 8 miles of main line track and 20 miles

STATEMENT SHOWING PRODUCTS RECOVERED FROM 100% CRUSHED KLONDIKE COAL

SIZE OF OVENS	CAPACITY	YIELD - ONE NET TON OF COAL.	
17" WIDE PUSHER SIDE	500 CU. FT.	1300 · LBS. SCREENED FURNACE COKE (2½% H_2O) (65% YIELD)	.57 GALS. PURE TOLUOL
19½" " COKE SIDE	13.3 TONS PER	120 · LBS. DUST (6% ")	.34 " CRUDE (#1) LIGHT SOLVENT
9'-10" HEIGHT OF OVEN	CHARGE @ 53.7 LB.	50 " DOMESTIC (2½% ")	.12 " " (#2) HEAVY "
9'-0" " " COAL	PER CU. FT. OF COAL.	26 " SULPHATE OF AMMONIA	.24 · LB. CRUDE NAPHTHALENE
37'-0" LENGTH OF OVEN		11 GALS. TAR	5814 · CU. FT. GAS SURPLUS (DEBENZOLIZED)
		1.93 · PURE BENZOL	4386 · " " OVEN FUEL (DEBENZOLIZED)

COKING TIME HOURS	NET TONS COAL PER OVEN PER 24 HRS	NET TONS FURNACE COKE PER OVEN PER 24 HRS	TOTAL NET TONS COAL 768 OVENS PER 24 HOURS	PRODUCTION PER 24 HOURS BASED ON 768 OVENS											
				NET TONS FURNACE COKE	NET TONS COKE DUST	NET TONS DOMESTIC COKE	NET TONS SULPHATE OF AMMONIA	GALLONS TAR	GALLONS PURE BENZOL	GALLONS PURE TOLUOL	GALLONS (#1) LIGHT SOLVENT (CRUDE)	GALLONS (#2) HEAVY SOLVENT (CRUDE)	NET TONS CRUDE NAPHTHALENE	1000 CU. FT. OF SURPLUS GAS · 57%	1000 CU. FT. OF OVEN FUEL GAS · 43%
19	16.80	10.92	12,892	8,380	773	322	167.5	141,812	24,882	7,348	4,383	1,547	1.547	74,954	56,544

FACTORS TO BE USED IN CONNECTION WITH ABOVE REPORT FOR VARIOUS COKING TIMES.

COKING TIME · HOURS	17	18	19	20	21	22	23	24
FACTORS	1.1176	1.0555	1.0000	.9500	.9047	.8636	.8261	.7916

COAL	FURNACE COKE	DOMESTIC COKE	COKE DUST	GAS	TAR	SULPHATE OF AMMONIA	PURE BENZOL	PURE TOLUOL	CRUDE (#1) LIGHT SOLVENT	REFINED (#1) SOLVENT	CRUDE (#2) SOLVENT	CRUDE NAPHTHALENE	PURE NAPHTHALENE
MOIST 2.89	2.50	9.00	13.53	CO_2 2.0	H_2O 1.25	H_2O 2.00	SPGR .883	SPGR .870	SPGR .870	SPGR .865	SPGR .920	DRY MP NOT BELOW 72°C	COLOR SNOW WHITE
V.M. 33.69	.74	.90	1.49	ILL. 3.2	L. OIL .18	ACID .20	MP 5.4°C	MP -92.4°C	MP BELOW -75°C	MP -80°C	MP -20°C	RESIDUE .3%	DRY MP NOT BELOW 79.4°C
FC 57.44	87.50	83.21	80.96	O_2 0.3	CARB. OIL 9.76	NH_3 25.10	DISTILLATION START 79.2°C	START 109.2°C	START 127°C	START 130°C	START 150°C	DISTILLATION NOT MORE	SPGR 1.152
ASH 8.87	11.76	15.89	17.55	CO 5.5	CRIO. OIL 11.49		5% OFF 80°C	5% OFF 110°C	3% OFF 130°C	5% OFF 133°C	5% OFF 156°C	THAN 6% OFF AT 200°C	WASH TEST NOT GREATER THAN #3
SUL 1.24	.89	.88	1.12	CH_4 32.3	ANTHRA-CENE 20.75		DRY 81°C	DRY 111°C	5% OFF 132°C	90% OFF 160°C	90% OFF 200°C	DECOMPOSITION	THE DISTILLATION
PHOS. .016	.020	.022	.022	H_2 51.9	PITCH 57.82		WASH #2	WASH #2	90% OFF 170°C	DRY 163°C	DRY 210°C	POINT BELOW	RANGE AFTER
BTU. 13,116	* 12,635	* 11,332	* 10,079	N_2 4.8	PITCH COKE 18.00	LIBERTY			DRY 174°C	WATER WHITE	LIGHT AMBER	250°C.	THE FIRST 5%
				SP.GR. .394	SPGR 1.156	H_2O .10			LIGHT STRAW COLOR				IS OFF, SMALL
				B.T.U. 568.95	VISCOSITY ENGLER AT 140°F 150	ACID .10							NOT BE MORE
				H_2S PER 100 CU FT .61	FREE C 5.59	NH_3 25.50							THAN 3°C.
				NAPHTHALENE GRS PER 100 CU FT	SUL .50								
				.95	BTU PER LB 16,325								

Table A. Prodution Data Sheet, Clairton By Product Coke Works.

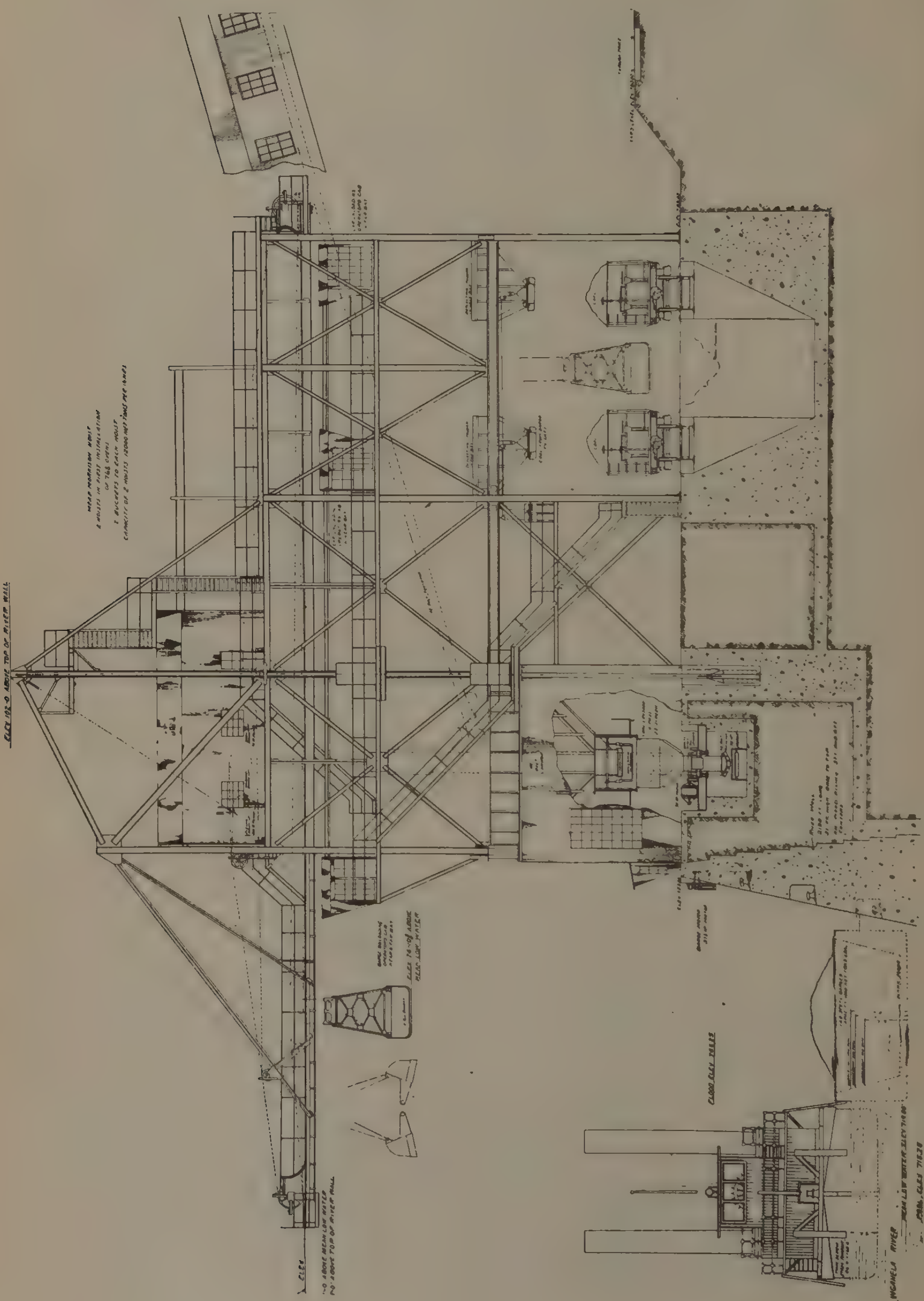
of yard track; a 40″ diameter gas line, 9 miles long, to deliver the gas to Duquesne, Homestead, Edgar Thomson and Clairton Steel Works; seventy-five 10,000-gallon tank cars for tar and benzol; 500 steel hopper coke cars; coal storage yard of 250,000 net tons capacity, to take care of a possible interruption in our river traffic in winter months and to assure uniform oven operation, etc.

The coking of 100% high volatile coal for the production of suitable metallurgical coke had not yet passed beyond the experimental stages when the Clairton plant was designed and considerable interest was centered upon the performance of the blast furnaces using this by-product coke made from 100% high volatile coal. The results obtained at the Clairton Steel Works blast furnaces soon demonstrated that the coke could be used successfully in place of beehive coke. Not only did these furnaces increase their production of pig iron, but they did so on a lower coke consumption; and the larger blast furnaces of Duquesne and Edgar Thomson, after some preliminary adjustments, quickly responded by increased production and low coke consumption in a manner most satisfactory.

In the description of this complete by-product plant it is difficult to convey a true conception of its size and operation, and I have therefore supplemented my paper with motion pictures to show upon the screen operations which would take many pages to describe.

To follow the plant construction in its sequence of operation, I have started at the coal hoists.

The Clairton Plant is equipped with two electrically operated coal hoists, each hoist consisting of two 5-ton hoisting buckets having a lifting capacity of 500 tons per hour. The coal is lifted from the barges and dropped into a 150-ton hopper, from which it is spread over a shaking screen to roll crushers. This screen has slotted openings 2½″ by 11″ and the crusher rolls are set 2″ openings, so that approximately 60% of the coal passes through the shaking screens, the oversizes going through the rolls,



leaving the rolls to crush only the large lumps. Thus we are able to secure a maximum density of coal; that is, there is always sufficient fines present in the coal to fill up the voids however coarse the coal may be crushed, and experiments have shown that by this method of crushing we are able to secure a coal of maximum density. Coal

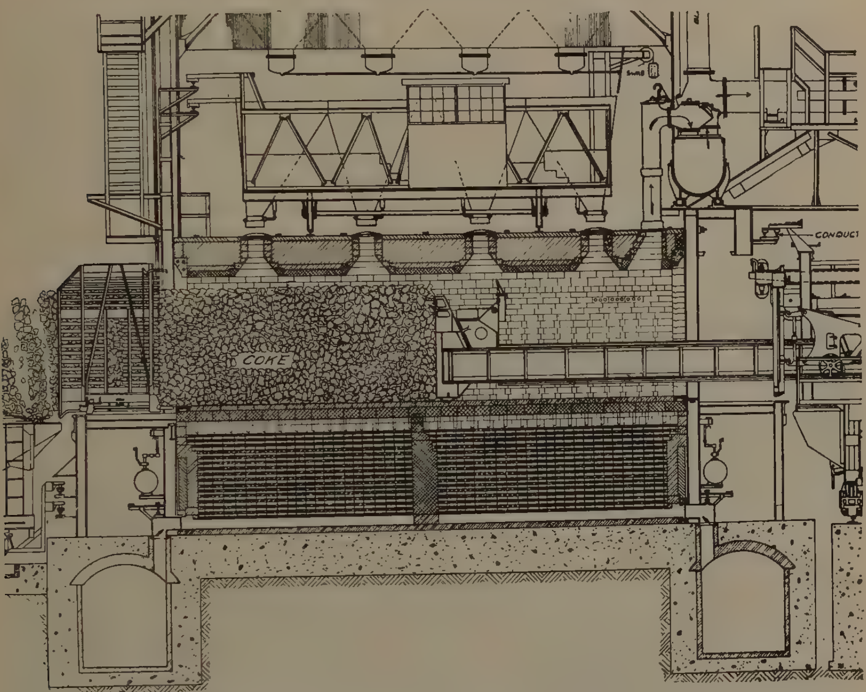


Figure 3—Cross Section of Oven, showing Oven Chamber, Larry Car, Regenerator and Flues

crushed in this manner will average 53½ pounds per cubic foot, while coal pulverized by hammer mills will average 6 to 8 per cent. less per cubic foot.

If we had been forced to resort to a mixture of low volatile coal, it would have been necessary to crush all of the coals to a small size in order to effect a thorough mixture. It has been demonstrated that the sizes to which the coal is crushed (a factor determining the density) has a direct influence on the quality of the coke and this important point in the operation of the coke plant should

receive very careful consideration. In the use of 100% high volatile coal, that is, volatile 33 to 35 per cent., I am convinced that the denser the coal charge the better the quality of coke.

The coal, after it leaves the crusher, is mixed with the fines that pass through the shaking screens and is fed on

Figure 4—Coke Screening Plant, Coke Wharf and Quenching Car

a rubber belt, then conveyed up a 15° incline to bunkers. The 12-battery plant is equipped with four bunkers, each bunker having a capacity of 4000 tons of coal. Each bunker supplies three batteries. The coal is drawn from the bunker into larry cars. These larry cars are equipped with four cone-shaped hoppers, the capacity of these being just sufficient to fill one oven which requires 13.3 net tons of coal per charge. It is important in the charging

of the ovens to see that the oven is charged to its fullest capacity, for the reason that not only do we secure thereby the maximum production of coke per oven but we limit the gas space in a manner which allows the gas to pass out of the oven quickly without lingering in contact with heated walls, such as would be the case where ovens are irregularly filled. The charging and leveling of the coal in the oven requires approximately one and one half to two minutes, during which time the gases are allowed to escape. As soon as the coal is leveled the lids are properly secured and the gas from the ovens is then allowed to pass up through the ascension pipe into the collecting main.

The ovens are Koppers Standard 500 cubic foot ovens, 37′ 0″ face to face of doors, 17″ wide on the pusher side and 19½″ wide on coke side, 9′10″ floor to roof and 9′0″ floor to top of coal when charged.

Each battery of 64 ovens is made up of 232 different silica shapes and 98 clay shapes. The total 9″ brick equivalent for each battery is approximately 2,529,000 bricks.

The ovens are individual cross-regenerative type, having 16 vertical flues on the pusher side and 14 vertical flues on the coke side, all connecting into a common horizontal flue near top of oven. Each oven has two independent air regenerating chambers filled up with 9″x3″x3″ and 9″x2½″x2½″ clay brick and 9″x2½″x2½″ silica brick, having a total mass of approximately 164 cubic feet in the pusher side chambers and approximately 152 cubic feet in the coke side chambers. The bottom tiers of regenerator brick are 9″x3″x3″ clay brick, so laid that the gas space between the bricks varies from ¼ of an inch on outlet side of chamber to ½ inch at far end of chamber, to more equally distribute the air through the checker work. All other brick are 9″x2½″x2½″ clay brick, except the top five courses which are 9″x2½″x2½″ silica brick.

That proportion of the gas which is returned to the ovens as fuel for heating same, is delivered to each bat-

tery through a Venturi meter and then to a 20″ O. D. main on each side of the battery. From the fuel gas main it is introduced alternately to each side of the ovens through gun brick made up of clay shapes having a 4″ diameter hole and suitable outlets on top to receive a nozzle brick for each vertical flue. The openings in the nozzle brick are semi-elliptical and vary from .49 sq. in. to .35 sq. in., increasing towards the center, furnishing a means of taking care of the pressure drop in gun brick and the changed volume of the heated gas. The nozzle bricks in the end flue, on each side, are of large size to make up for radiation losses caused by the oven doors.

The air for combustion enters the regenerator chambers under suction through air valves in the connection between the bottom regenerator chamber and the side stack flue. This inlet is opened and closed by the automatic reversing mechanism, being open when the reversing damper on the same side is closed. The amount of air entering can be controlled at this point by more or less restricting the opening by the use of strips of steel called finger bars. The air passes up through the regenerators, is heated to 1700°F. (927°C.), and enters the vertical flues, where combustion takes place. These air openings into the vertical flues are 6.213 sq. in. in area, except the end flue, which is 9.281 sq. in., to supply additional air for the greater amount of gas burned in the end flue. Each vertical flue is continued above the horizontal flue to the top of the battery where it is covered by a cast iron cap. This cap furnishes a means of inspecting each flue and also a means of changing nozzle brick or sliding brick settings.

The opening from each vertical flue into the common horizontal flue is regulated by a sliding brick in order to secure uniform pressure condition in each vertical flue. The gas is burned up the vertical flue in such a manner that the tip of the flame extends approximately 24″ from the top horizontal flue.

The products of combustion are conducted from the

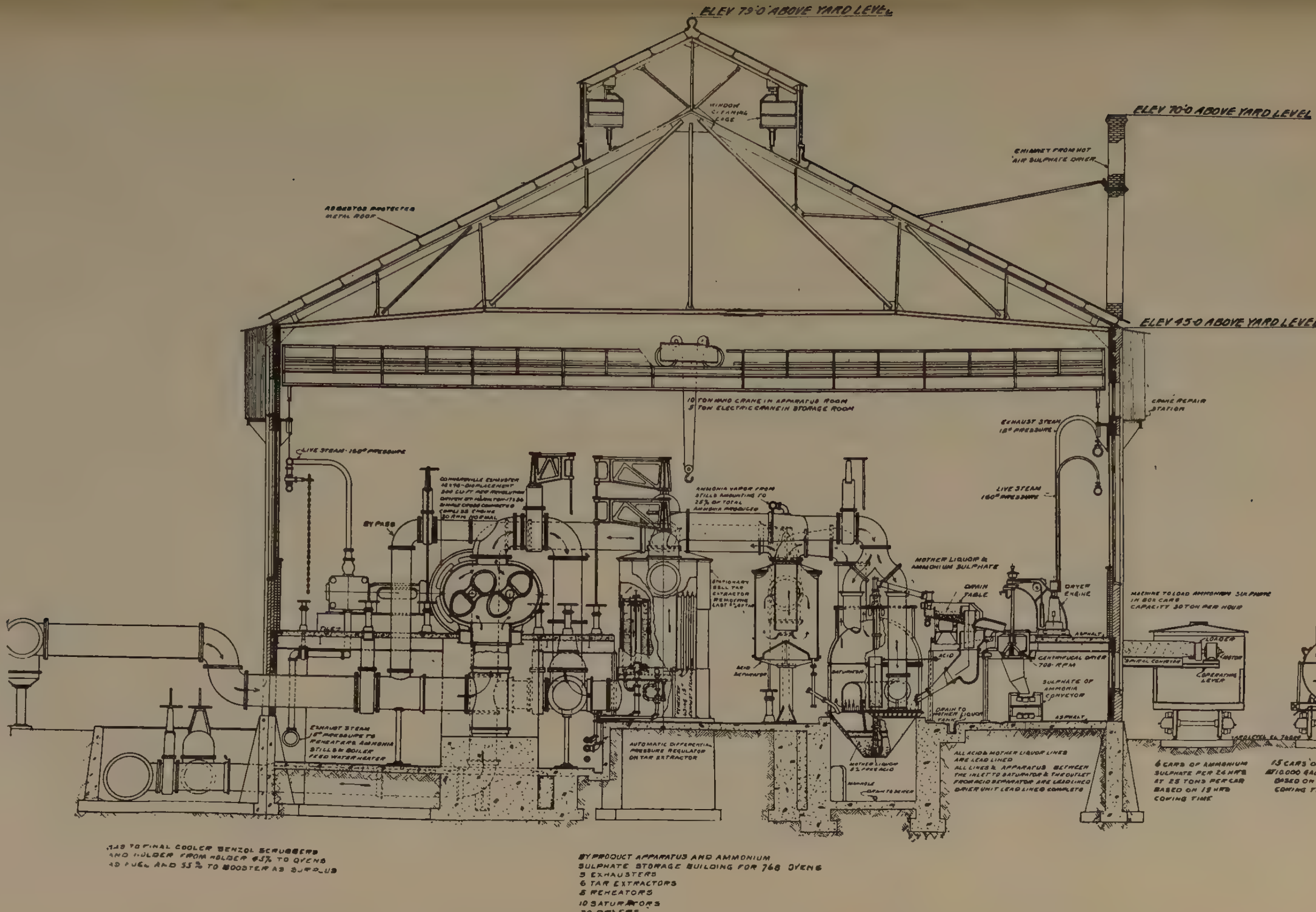


Figure 5—Cross Section of By-Product House and Apparatus-Exhaustor, Tar Extractor, Acid Separator, etc.

vertical flues on one side of the oven into the horizontal flues, across and down through the vertical flues on the other side and through air ports into opposite regenerator chambers where the gas is robbed of most of its sensible heat. From the regenerator chamber the waste gas is conducted through the air box to the stack flue, thence to the stack. On 19 hour coking time the average vertical flue temperature on low heated coke is 2300°F. (1260°C.).

The draft on individual ovens is controlled by a butterfly damper in each air box, connecting the regenerators with waste gas flue leading to the stack. The butterfly dampers are set wide open for the regenerator farthest away from the stack end and gradually contracted toward the stack so that each regenerator of the entire battery of 64 ovens is under the same draft conditions; individual ovens, however, may be given more or less gas to compensate for variable conditions that may exist.

The stack flues parallel each side of the battery, uniting into a single flue at the reversing end of the battery, thence to the stack. The stacks are built of reinforced concrete, brick lined, are 8′6″ in diameter and 200′0″ high. At a point near the junction of the two main flues, each flue has a reversing and regulating damper. The reversing damper, during operation, is either wide open or closed according to the side the gas is burning on. The regulating dampers have hand control and when once set are left in position as long as the desired differential exists between the two flues. The main stack flue has a hand regulated damper by which the draft may be regulated, affecting both flues without affecting the distribution of draft between the coke and pusher side flue.

Summary of the Points of Variable Control

(1) Pressure of gas in fuel gas main on each side of battery.
(2) Size of opening in nozzle brick in each vertical flue.
(3) Setting of sliding brick at top of each vertical flue.

(4) Setting of draft butterfly dampers in air boxes from stack flues.

(5) Setting of regulating dampers in pusher and coke side stack flues.

(6) Setting of regulating damper in main stack flue.

(7) Number of finger bars in air inlet to regenerators.

It can readily be seen that these points of regulation are all more or less interdependent and furnish a very flexible means of control.

The gas is reversed every half hour by a clock energizing a motor driven master control. First, the gas is shut off by closing individual valves in the line from the fuel gas main to the gas gun. The valves on either side of the battery are all connected by a rod and cable to separate gas cock machines. Second, the reversing dampers are reversed, the same machine reversing the air opening in the air box. Third, the gas cocks on the opposite sides are opened. The gas is put on by the gas cock machine releasing cable allowing counterweight to open cocks. The gas is taken off by the machine pulling against the counterweight and is positive in action.

The various steps in reversing are so timed that enough time interval is allowed between each operation for the flues to clear themselves of any explosive mixtures. Every operation—reversing, gas pressure, temperature, gas consumption, etc.—is recorded by clock recording instruments.

Inasmuch as the gas is introduced through the gun brick and nozzles, located in such position in the oven that they become heated to a point high enough to break up some of the fuel gas with the deposition of carbon, it is necessary to provide means of decarbonizing them. This is done by opening the cap on each gas gun several minutes after reversal on the opposite side from which the gas is burned, allowing air to be drawn into gun brick and nozzles, burning the heated carbon.

THE FOLLOWING ARE CLAIRTON AVERAGE SETTINGS AND READINGS ON 19-HOUR COKING TIME

Gas pressure on pushing side	40 mm of water
Gas pressure on coke side	50 mm of water
Stack draft on pusher side	21 mm of water
Stack draft on coke side	22 mm of water
Temperature of waste gas at base of stack	275°C
Gas burned per hour, pusher side	180,000 cu. ft.
Gas burned per hour, coke side	200,000 cu. ft.
Back pressure in collecting mains	2.5 mm of water
Average draft at top of regenerator chamber—pusher side—	.36″ water
Average draft at top of regenerator chamber—coke side—	.40″ water
Opening in air inlet to regenerators—pusher side—	59.7 sq. in.
Opening in air inlet to regenerators—coke side—	84.7 sq. in.

NOZZLE BRICK SETTINGS

Flue 1—coke side (end flue)	.49 sq. in. or 316.05 sq. mm
" 2 to 12 incl. coke side	.35 " " " 225.70 " "
" 13 and 14 " "	.38 " " " 245.10 " "
Flue 1—pusher side (end flue)	.35 " " " 225.7 " "
" 2 to 12 incl. (pusher side)	.35 " " " 225.7 " "
" 13 to 16 " " "	.38 " " " 245.1 " "

SLIDING BRICK SETTINGS

Flue No. 1	Coke side (end flue)	full open	17.721 sq. in.
" " 2, 3, 4	" "	60 mm	8.103 " "
" " 5, 6, 7	" "	55 mm	7.256 " "
" " 8, 9, 10, 11, 12	" "	50 mm	5.874 " "
" " 13, 14	" "	45 mm	5.119 " "
Flue No. 1	Pusher side (end flue)	full open	17.721 " "
" " 2, 3, 4, 5	" "	60 mm	8.103 " "
" " 6, 7, 8	" "	55 mm	7.256 " "
" " 9, 10, 11, 12	" "	53 mm	6.615 " "
" " 13	" "	50 mm	5.874 " "
" " 14, 15, 16	" "	45 mm	5.119 " "

After the volatile matter is all driven off from the coke, which at present is completed in 19 hours, and which can be accomplished in less time, the doors are removed and the coke is pushed into the quenching car and is brought under a spray of water and quenched for 45 seconds. In order to quench the coke in this time 6,000 gallons of water per quench are required, 1,000 gallons of which evaporate. It is important to quench the coke in a manner which will give a coke containing not more than 3% of water. The coke is then allowed to drain one minute and dropped upon a wharf, from which it is fed by a rotary feed to a rubber belt, passed over a stationary bar grizzly screen, made up of hard iron bars set with space ⅞″ top and 1¼″ bottom, 6 sets of bars, each bar 24″ long, and through chutes into cars. The fines passing through the grizzly screen amount at present to approx-

imately 18% of the total coke discharged from the oven. These fines are rescreened through a rotary screen with ¾″ wire mesh openings, where the larger sizes are separated from the dust. The larger sizes are available for domestic fuel, while 80% of the dust is required to produce all the steam requirements for the entire coke and benzol plants.

The gas coming from the ovens enters a collecting main through ascension pipes and mushroom valves. The collecting main is "U" shaped and so designed as to give the gas a speed of approximately five feet per second, and the suction main is so designed as to give a speed of travel of approximately fifteen feet per second. In order to maintain uniform gas pressure in the collecting main a butterfly regulating valve is inserted in the suction main and is controlled by an electric contrivance known as a Northwestern governor. This valve is set so as to hold a pressure in the collecting main at 3½ mm. of water.

The gas leaves the ovens at an average temperature of 600°C., enters the collecting main at 400°C. and leaves the collecting main to the suction main at 200°C.

The heavy tars are quickly condensed and drop out in the collecting mains and, in order to prevent this pitchy tar from building up and stopping the mains, a constant stream of what is known as flushing tar is flooded through these mains. This flushing tar is a mixture of 50% tar and 50% ammonia liquor. This carries the heavy tar and such pitch as is formed to the end of the main, where the hard pitch is screened out and removed. The gases in their travel from the ovens to the primary coolers are reduced 200°C. to 75°C. During the cooling, 70% of the tar is condensed in the collecting mains before the primary coolers are reached, 20% is condensed in the suction mains and approximately 8% of the lighter tars and most of the water vapors are condensed in the primary coolers. The temperature in the gas inlet to the primary coolers is 75°C., while the outlet from the primary coolers is 28°C. The liquor and tar are combined and the mixture flows to

a circulating drain tank, from which it is pumped to the tar separating tank.

In order to maintain uniform operating conditions it is extremely important that the even temperature control of the gases be constantly maintained. After the gases are passed through the primary coolers, they are under a suction of 30 cm. of water. The Clairton Plant is equipped with five Connersville exhausters, each having a capacity of 40,000,000 cu. ft. per 24 hours at 100 R. P. M. Each exhauster is driven by two simple, non-condensing, direct connected Hamilton engines, built by the Hooven, Owens and Rentschler Company.

After passing through the exhauster, the gas is raised in temperature by compression, from a suction of 15″ of water to a compression of 50″ of water. The gas is then passed through the tar extractors, which eliminate the last traces of tar vapors by mechanical means, i.e., forcing the gas through finely perforated plates and allowing it to impinge upon a flat surface, which breaks up the little tarry mist into globules. The gas, thus free from the tar, is preheated to a temperature of 60°C., and then passed through the lead lined saturators containing a solution of 5% sulphuric acid. The gas, coming in contact with this acid, gives up all of its ammonia which forms ammonium sulphate ($(NH_4)_2SO_4$). After this acid bath becomes saturated, the crystals of ammonium sulphate fall to the bottom and are ejected by an air syphon ejector and thrown upon a draining table. The mother liquor is returned to the saturator and the salt is periodically paddled into the centrifugal dryer.

These dryers are 40″ in diameter and have a copper screen perforated with 5/64″ holes, backed up with 18 gage, 11 strands to the inch, copper wire mesh, with copper screen perforated with 5/16″ holes on the outside, and during the drying process are speeded up to 650 R.P.M. The salt is built up on the walls of this centrifugal dryer to the extent of 4″ or 5″ and is whizzed for a period of 15 minutes, after which it is washed with a small quantity of

hot water and whizzed for another few minutes. The dryer is then stopped and the salt is scraped off the copper screen with copper paddles and dropped upon a rubber conveying belt and is discharged into a revolving drum dryer known as air-heated dryer in which the moisture is reduced from 2% to less than ¼ of one per cent.

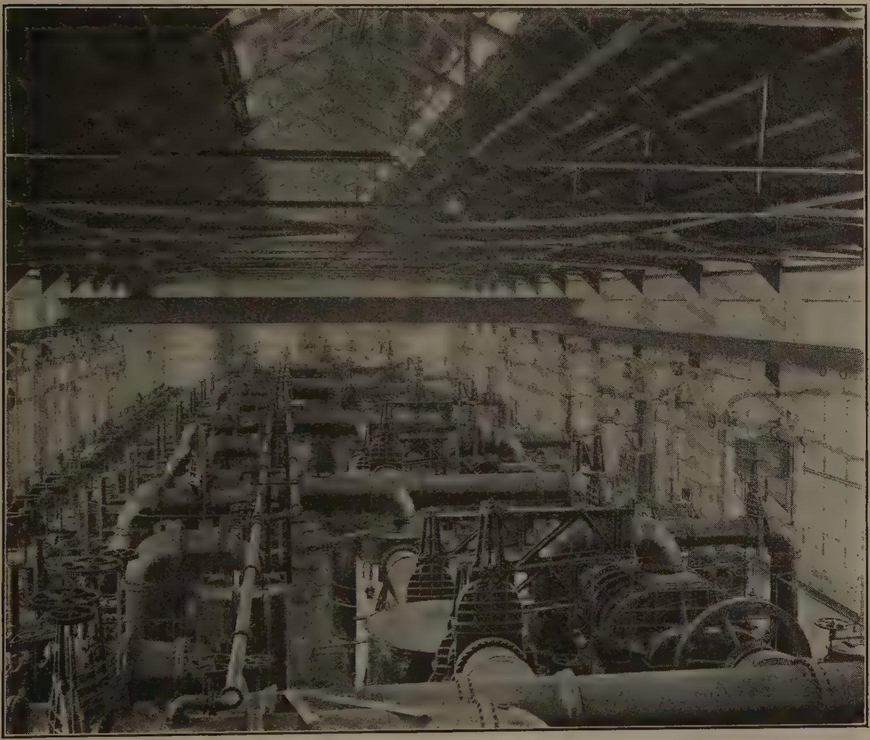


FIG. 6. Interior View of By-Product Building

The normal specifications of sulphate of ammonia call for a sulphate of ammonia containing not under 25.00% ammonia (NH_3). This would enable us to have a moisture content not to exceed 2%. However, a considerable demand exists for a very dry sulphate, in which the moisture content is reduced to less than .15% and the acid content under .15%. In order to secure these results, the air-heated dryer drum has been introduced and this high grade quality procured.

Practically all the sulphate of ammonia is used as a fertilizer—in some cases blended with bone dust and in many cases used without mixing with bone dust or phosphates or other fertilizing mediums. From the analyses of the coal it will be noted that it contains approximately 5% of combined water and 3% of free water, making a total of 8% of water. This water is condensed and dissolves out of the gas and the tar a certain amount of ammonium sulphide and ammonium carbonate and practically all of the chloride of ammonia. Thus the ammonia which is taken out of the gas by this water amounts to approximately 20% of the total ammonia content of the gas.

This weak liquor, as it is called, contains about 1% of total ammonia (NH_3), is separated from the tar by gravity, in separating tanks, and is put through ammonia stills where it is brought in intimate contact with a solution of lime water and steam. The lime combines with the ammonium chloride forming calcium chloride, and the ammonia is driven off as a gas and is led through cast iron pipes into the gas mains before the saturators, all being converted into sulphate of ammonia. If, however, there is a market for concentrated ammonia liquor, the ammonia gases from the ammonia stills, instead of being conducted to the saturators, are condensed into liquor and sold as ammonia liquor containing 20% to 25% NH_3.

The tar, after it has been allowed to settle and the ammonia liquor separated (which takes place by gravity), is then loaded into tank cars of 10,000 gallon capacity. Most of the tar is shipped to the open-hearth and heating furnaces, where it is burned in connection with coke oven gas as a fuel for the production of open-hearth steel, and the remainder is disposed of to various tar-using industries.

The following is a typical analysis of Clairton coal tar:

Moisture	1.25%	
Specific gravity	1.156 (at 15°C.)	
Viscosity	140 at 60°C. (Saybolt method)	
Free carbon	4.25%	
B.T.U. per pound	16,200	
Sulphur	.55%	
Distillation—		
Light oil (0° to 170°C.)	.20%	
Carbolic oil (170-230°C.)	9.60%	3% carbolic acid 6% cresylic acid
Creosote oil (230-270°C.)	10.20%	
Anthracene oil (270-350°C.)	23.00%	
Pitch (at 350°C.)	57.00%	
Coke residue (at 1200°C.)	17.20%	

Figure 7—Ammonia Sulphate Storage Room

After the gas passes the ammonia saturators, it is passed through final coolers where it is brought in direct contact with a water spray and cooled from 60°C. to 25°C., at which temperature it is passed through the oil scrubbers.

These oil scrubbers, arranged three in a series, are 16′0″ in diameter and 100′0″ high, filled up with wooden grids for 80′0″ in such a manner that the oil, which is trickling down through the grids from a series of 24 sprays at the top, comes into intimate contact with the gas. The wash oil, as it is called, absorbs the benzol vapors from the gas. These oil scrubbers are so designed that the gas will have a speed of not under 3 feet per second and a time of contact through the series of three scrubbers of not less than 60 seconds. In this manner 90% to 96% of all the benzol vapors are extracted from the gas at a temperature of 25°C. and the oil will have a saturation of 2½ to 3% of benzol and its homologues.

The gas, after it has been debenzolized, is metered by a Thomas meter, i.e., an electric meter, which measures the current required to heat up the gas 2°C., after which it is passed to a 100,000 cubic foot regulating holder. Forty-three per cent. (43%) of this gas is required for heating up the ovens, while the remaining 57%, which is designated "surplus gas," is sent to the booster station where it is boosted by steam driven turbines to a pressure of 7 pounds and delivered through a 40″ gas main for a distance of 6 to 9 miles, supplying gas to the steel mills at Clairton, Duquesne, Homestead and Braddock. The following is a typical analysis of Clairton debenzolized (fuel) gas:—

Carbon dioxide (CO_2)	1.8%	by volume
Carbon monoxide (CO)	3.5%	"
Illuminants (C_2H_4)	3.0%	"
Methane (CH_4)	36.6%	"
Hydrogen (H_2)	53.9%	"
Nitrogen (N_2)	3.2%	"
B.T.U.'s, Calculated	582.9	
Hydrogen sulphide as Sulphur, pounds per 1,000 cu. ft.	.75 Lbs.	

The wash oil, thus saturated with benzol and its homologues to the extent of 2½ to 3%, is pumped to the wash oil stills at the benzol plant, where it is heated up to a temperature of 150°C. through superheaters, then led into the wash oil stills where it is brought into contact with live

steam where the benzol vapors are driven out of the wash oil. These are condensed and separated from the water and form what is known as light oil. The wash oil, thus debenzolized to a point where it contains less than .3% light oil, is cooled off through pipe coolers and returned to the scrubbers to take up another load of benzol.

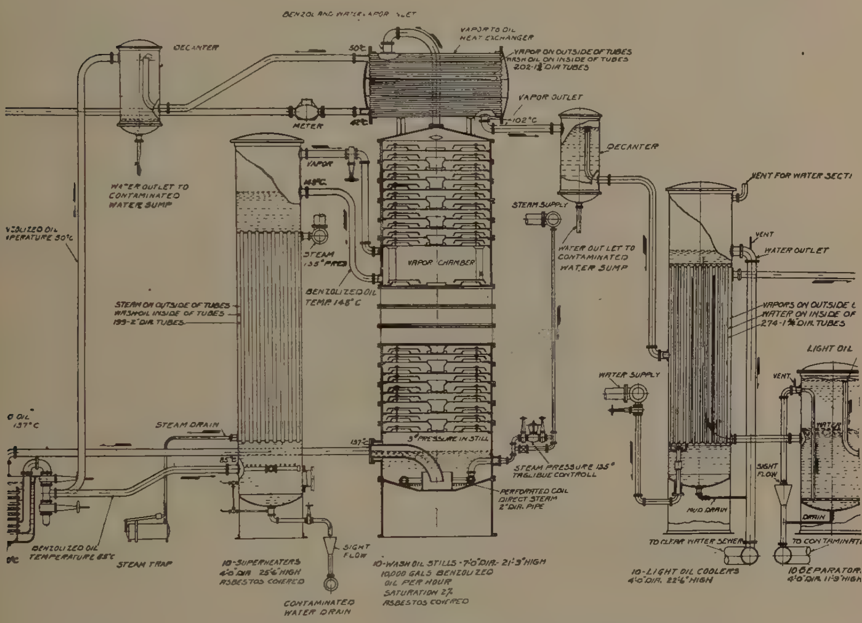


Figure 8—Cross Section showing Oil Superheater, Wash Oil Still, etc.

The light oils coming from the light oil stills contain approximately 8% of wash oil and naphthalene. This wash oil and naphthalene are removed by distilling the light oils in an intermittent still known as a crude still (capacity 20,000 gallons), thus approximately 92% of the benzol and its homologues are distilled off, leaving a residue of naphthalene and wash oil. This residue is drawn into a decanter tank and forced by air pressure into cooling pans where the naphthalene is crystallized out and the wash oil is returned to the circulating system.

The light oil analysis is approximately as follows:

Crude Benzol	63%
Crude Toluol	16%
Crude No. 1 Solvent	8%
Crude No. 2 Solvent	5%
Wash Oil and Naphthalene residue	8%

In this crude distillation the total benzol fractions with the exception of the heavy No. 2 Solvent are combined, while the heavy solvent is separated. The combined benzol fractions are then pumped into a lead-lined agitator which is capable of holding 10,000 gallons of crude benzol. Then .4 pound of 66° sulphuric acid per gallon of product is added (acid being added in small quantities)

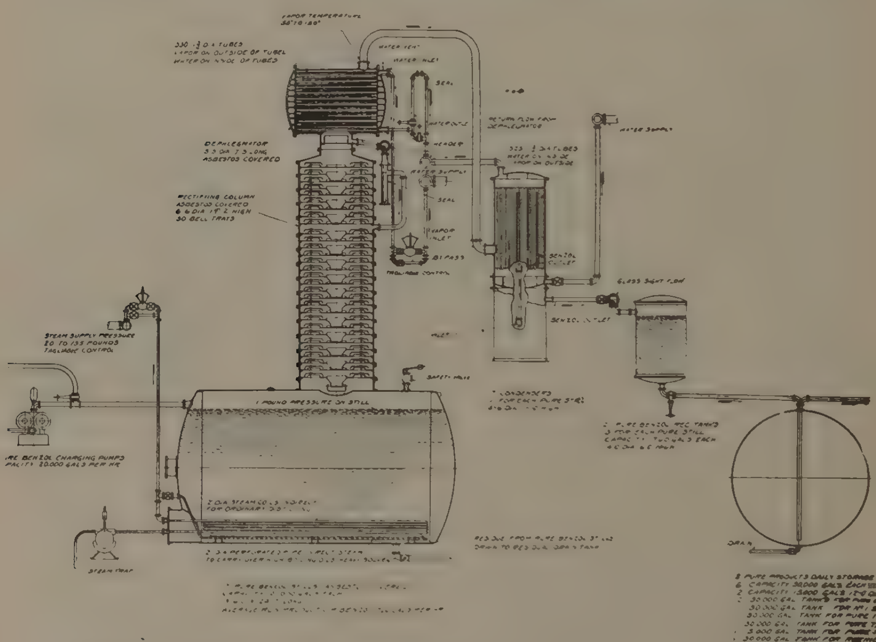


Figure 9—Cross Section of Pure Still, Dephlegmator, Condenser and Receiving Tank

and the content is agitated for a period of three hours, after which the sludge, which consists mainly of thiophenes and unsaturated hydrocarbon compounds, is removed and drawn off into an acid pot. After the benzol is sufficiently washed with acid, which is determined by laboratory tests, it is then washed with water and neutral-

ized with a 10% solution of caustic soda. The water and the caustic soda are drawn off and this washed benzol product is then pumped to the pure stills where the product is either fractionated into pure products or refined into mixed products, according to the market requirements. The loss sustained in washing amounts to 9% of the product washed, while the loss sustained in the pure stills amounts to 8% of the product in residue and noncondensable gases.

Equipment for Clairton By-Product Coke Plant

The plant equipment consists of two (2) complete coal handling units, each unit supplies two 4,000-ton bunkers, and each unit has the following equipment:

1 coal hoist; two 5-ton grab buckets; 2 shaker screens; 2 duplex roll coal crushers; 1 conveyor 210′0″ long, belt 42″ wide; 1 conveyor 345′0″ long, belt 42″ wide; one belt is equipped with automatic scale, capacity 500 net tons per hour; one conveyor, from bunker to bunker, 242′0″ long, 42″ belt; each bunker is equipped with shuttle conveyor, 34′0″ long, belt 42″ wide.

Ovens and Oven Equipment.

Twelve batteries, 64 ovens each, 768 ovens total; size of oven—17″ wide on pusher side, 19½″ wide on coke side, 9′0″ from oven floor to top of coal, 9′10″ from oven floor to top of oven, oven 37′0″ long, 500 cubic foot capacity, 13.4 net tons coal. Twelve stacks 8′6″ diameter, 200′0″ high, reinforced concrete, brick lined. Twelve complete clock controlled automatic gas, air and stack damper reversing mechanisms. Six (6) coal charging larries, four bin type, each equipped with swab crane. Eight (8) pusher machines, equipped with pusher ram, reciprocating leveler bar, and door remover. Four (4) spillage pits. Eight (8) coke guides. Twelve (12) clay carriers on pusher side, and fourteen (14) clay carriers on coke side. Eight motor operated door extracting machines. Eight (8) quenching cars and eight (8) electric locomotives. Four (4) quench-

FIG. 10. President Farrell of the United States Steel Corp., and President Williams of the Carnegie Steel Company, leading inspection party during construction of By-Product Coke Plant, accompanied by General Superintendents of Carnegie Steel Company, and local Superintendents of By-Product Coke Plant and Steel Plant

ing stations, one to three batteries; tank capacity for each quenching station 14,000 gallons; 1 pump house for each 2 quenching stations; two 2,500,000-gallon motor driven centrifugal pumps at each pump house. Four (4) coke wharves each 164′0″ long, capacity of four oven charges each, rotary feeders to conveyor belt; one (1) four-unit screening station, one unit for each coke wharf; conveyor from each wharf 42″ belt, 450′0″ long; 4 grizzly screens for furnace coke, six sections each, first section cross bars 1″ spacing, five sections longitudinal bars spacing 7/8″ on top and 1 1/8″ at bottom; two breeze conveyors, 100′0″ long, 18″ belt; two (2) rotary screens for domestic coke and dust, 5/16″ wire screen drum, 5′0″ diameter, 16′ 0″ long, 7/8″ square openings, 12 R. P. M.; four (4) 35-ton electric locomotives, combination third rail and storage battery type, remotely controlled, for handling furnace coke under screens to yard scales; one 200-ton capacity yard scale; ten (10) primary coolers, indirect tubular type, 2219 3″ 20′0″ long.

By-Product Building and Salt Room Equipment.

Size of by-product building proper, 92′0″ wide, 303′0″ long; salt room, 92′0″ wide, 456′0″ long; total building, 92′0″ wide by 759′0″ long.

Five (5) positive exhausters, capacity 40,000,000 cubic feet of gas per 24 hours each, direct connected to 17″x36″ heavy duty, twin Hamilton Corliss engines, 85 to 125 R. P. M. Six tar extractors, 7 bells each; differential gas pressure Tagilabue control; 5 reheaters; 10 saturators; 30 centrifugal dryers, belt driven by vertical steam engines, 20 H. P.; 10 acid separators; 2 mother liquor tanks, 1 lead lined; 3 air compressors, steam driven, capacity 600 cu. ft. of air per minute each; one (1) 5-ton hand operated crane. Salt room storage capacity 22,000 tons, 5 months production; one 5-ton electric travelling crane; 1 salt conveyor from dryers, 360′0″ long, 24″ belt; 1 rotary salt dryer (air dryer); 1 gas furnace for rotary dryer; 2 hanging scales and bagging hoppers; 1 bag sewing machine; 1 box car loader.

Still, Lime and Pump Room.

Two (2) 40,000 gallon capacity hot drain tanks; 4 centrifugal tar flushing pumps, motor driven, capacity 3,000,000 gallons per 24 hours each; 2 triplex vertical pumps (spares), 1,000,000 gallons capacity each, direct connected to steam engine; 4 hot drain centrifugal pumps, motor driven, capacity 300,000 gallons per 24 hours each; 4 ammonia feed centrifugal pumps, motor driven, capacity 200,000 gallons per 24 hours each; 6 free ammonia stills, capacity 3000 gallons per hour each; 6 fixed stills; 6 vaporizers; 6 dephlegmators; 6 condensers.

One lime storage room, 100 net tons capacity; 1 lime breaker; 1 lime conveyor; 1 lime slacking drum; 1 centrifugal lime feed pump, motor driven.

Storage Tanks.

Four (4) 500,000 gallon tar tanks; two 300,000 gallon ammonia tanks; two 372,000 gallon tar and liquor separating tanks; two 90,000 gallon concrete basins for concentrated ammonia; four 40,000 gallon tanks for 60° Be. acid; one 6,000 gallon tank for 40° Be. acid.

Tar Loading Station.

One (1) 100,000 gallon loading tank; 1 tar loading pump house; 1 centrifugal tar loading pump, motor driven, 360,000 gallon capacity per 24 hours; 1 triplex pump, motor driven, 360,000 gallons per 24 hours; 45 tar tank cars, 10,000 gallon capacity each.

EQUIPMENT FOR BENZOL RECOVERY PLANT.

Four (4) final coolers, 12′0″ diameter, 100′0″ high; 4 naphthalene pumps; 2 vertical centrifugal naphthalene pumps, motor driven; 12 oil scrubbers, 16′0″ diameter, 100′0″ high.

One (1) wash oil circulating pump house; 10 centrifugal oil pumps, motor driven, capacity 1,000,000 gallons each per 24 hours; 2 wash oil circulating tanks, 50,000 gallon capacity each.

Six (6) Thomas meters, capacity 1,500,000 cu. ft. of gas per hour each; one 100,000 cu. ft. gas holder; 2 gas bleeders, 36″ diameter, 100′0″ high.

One (1) surplus gas booster station; 3 Ingersoll-Rand turbo blowers, driven by high pressure condensing steam turbines, capacity 70,000,000 cubic feet of gas per 24 hours each, at 7° discharge pressure, 2800 R. P. M.; 1 Ingersoll-Rand condenser and vacuum pump.

One (1) cooling tower, combination forced and natural draft; 3 fans, 12′0″ diameter, motor driven, capacity of tower 10,000,000 gallons of water per 24 hours, for cooling water used on direct final gas coolers.

One (1) water recirculating pump house; 2 centrifugal pumps, motor driven, 10,000,000 gallons capacity per 24 hours each, for final cooler water; 2 centrifugal pumps, motor driven, 10,000,000 gallons capacity per 24 hours each, for circulating water over cooling tower; 2 centrifugal pumps, motor driven, 1,000,000 gallons per 24 hours each, for well water over final coolers; 10 deep well pumps, 50,000 gallons capacity each per 24 hours, for final gas coolers.

The light oil recovery plant consists of 10 light oil stills, each equipped with rectifying column; vapor to oil heat exchanger; decanter; oil to oil heat exchanger, superheater; light oil cooler; light oil separator and decanter tanks. Two (2) hot oil drain tanks, 30,000 gallon capacity each, for debenzolized wash oil.

One (1) debenzolized oil pump house; three (3) cycloidal pumps, 40,000 gallon capacity per hour each, driven by steam engines; 1 triplex pump, electric driven, capacity 200,000 gallons per 24 hours for handling contaminated water to quenching stations; 1 duplex pump, steam driven, 120,000 gallons per 24 hours, for unloading wash oil and pumping oil back into system; four 8″ oil lines, each 5000 feet long, two for benzolized and two for debenzolized oil; 1 set wash oil coolers, 80 banks, open type; 2 wash oil circulating tanks, capacity 50,000 gallons each.

Benzol Refining Plant.

Two (2) crude stills, each holding a 20,000 gallon charge, with columns and dephlegmators; benzol coolers; separators and receiving tanks. Seven pure benzol stills, each holding 20,000 gallon charge, with rectifying columns and dephlegmators; coolers; receiving tanks. One (1) residual drain tank, 7000 gallon capacity; 1 wash oil drain tank, 7000 gallon capacity; 3 duplex steam driven charging pumps, capacity 20,000 gallons per hour each; 1 steam driven air compressor, 50 cu. ft. of air per minute for Tagliabue control system; 2 vacuum pumps, steam driven; 1 ventilating fan; 2 pneumatic sample transmission stations; 1 hand operated crane, 15-ton capacity.

Agitator Building.

Four (4) agitators, 10,000 gallon capacity each, steam driven; 2 air compressors, steam driven, capacity 200 cu. ft. per minute each, for acid and soda solution charges; 4 meter tanks, capacity 500 gallons each, for acid; 2 meter tanks, 500 gallon capacity each, for soda solution; 3 duplex charging pumps, steam driven, 20,000 gallon capacity each per hour, to charge agitators; 1 travelling beam with chain blocks, 5-ton capacity; 1 acid feed tank, 6000 gallon capacity; 1 soda feed tank, 6000 gallon capacity; 1 ventilating fan; 1 soda mixing tank, 600 gallon capacity; 1 soda discharge tank, 600 gallon capacity; 2 acid storage tanks, 15,000 gallon capacity.

Acid Boilers.

Eight (8) acid boilers, tilting type, to boil acid sludge from agitators; 8 overhead suspended, electric motor driven, chain hoists, capacity 10 tons, one for each boiler; 1 acid filter, lead lined, with filter brick; 2 acid neutralizing pots; 2 acid vapor condensers; 1 benzol drain tank, 500 gallon capacity; 2 acid drain tanks, lead lined, 6000 gallon capacity each, for regenerated acid; 1 acid transfer car, 6000 gallon capacity, lead lined.

Daily Product Storage Tanks.

2 30,000 gallon, pure benzol.
1 30,000 gallon, (No. 1) light solvent.
1 30,000 gallon, pure intermediate benzol.
1 30,000 gallon, pure intermediate toluol.
1 30,000 gallon, refined first runnings.
1 15,000 gallon, pure xylol.
1 15,000 gallon, pure toluol.
1 30,000 gallon, pure toluol.
1 30,000 gallon, crude first runnings.
2 30,000 gallon, crude (No. 1) light solvent.
1 30,000 gallon, crude (No. 2) heavy solvent.
2 30,000 gallon, crude toluol.
2 30,000 gallon, crude benzol.
1 30,000 gallon, washed benzol.
1 30,000 gallon, washed toluol.
1 30,000 gallon, washed solvent.
2 30,000 gallon, crude light oil.

Storage Tanks.

1 100,000 gallon, crude (No. 1) light solvent.
1 100,000 gallon, pure toluol.
1 100,000 gallon, pure benzol.
2 250,000 gallon, pure benzol, equipped with steam coils.
1 250,000 gallon, new wash oil.
2 250,000 gallon, crude light oil.
1 50,000 gallon, old wash oil, with steam coils.

Crude Naphthalene Plant.

Twelve (12) crystallizing pans, 2500 gallons each; 2 centrifugal dryers, steam driven, 400 pounds capacity each. One (1) crude naphthalene storage room.

Loading Dock.

One (1) loading building, 25′0″ wide, 60′0″ long; 2 loading platforms, 30′0″ wide and 80′0″ long, each; 4 loading tanks, 2000 gallons capacity each; 2 duplex loading pumps, steam driven, capacity 10,000 gallons per hour

each; 2 platform scales for weighing drums; 5000 benzol drums, capacity 110 gallons each; 35 benzol tank cars, 10,000 gallons each, equipped with steam coils.

Benzol Boiler House.

Six (6) 600 H.P. Sterling boilers equipped with Cox chain grate stokers, soot blowers and superheaters; 2 blowers, turbine driven; 1 feed water heater, cylindrical, for exhaust steam, 20,000 H.P. capacity; 2 steam driven duplex horizontal feed pumps, capacity 600 gallons per minute each; 3 reinforced concrete stacks, one for each two boilers, brick lined, 6′6″ I. D. 160′0″ high; 1 ash hoist operated with skip car; 1 ash gathering car, motor driven; 1 coke dust conveyor, 24″ belt.

Fire Protection.

One (1) pump house; one 3-stage centrifugal pump, 1,500,000 gallons capacity per 24 hours; 230 pound discharge pressure, 200 H.P. motor; 4 two-way fire plugs.

A complete installation, designed and installed by the Firefoam Company, for the purpose of extinguishing benzol fires on all storage tanks, including two 50,000 gallon solution tanks, one pump and individual mixer on the top of each benzol storage tank.

Drinking Water System.

One (1) deep well pump, 50,000 gallons capacity per 24 hours.

Power Transformer Station.

One (1) transformer station, 6600 volts to 250 and 110 volts, for electric power and light required at Benzol Plant.

Office Building.

One (1) laboratory, office, police and sanitary station combined for Benzol Plant.

Water, Steam and Power Installations.

River Pump House.

Three (3) 24″ Wilson-Snyder horizontal centrifugal pumps, 20,000,000 gallons capacity per 24 hours, each;

driven by 1000 H.P. Westinghouse motor, 6600 volts, 25 cycle, 2 phase; one 15-ton electric travelling crane; 1 stand pipe, 24′0″ diameter, 125′0″ high. Water requirements 40,000,000 gallons per 24 hours.

Boiler House.

Fourteen (14) 600 H.P. Sterling boilers, equipped with Cox stokers, superheaters and soot blowers; 3 steam turbine driven blowers; 1 feed water heater, cylindrical, for exhaust steam, 20,000 H.P. capacity; 3 steam driven duplex horizontal feed pumps, capacity 600 gallons per minute each; 7 reinforced concrete stacks, one for each two boilers, brick lined, 6′6″ I.D., 160′0″ high; 1 ash hoist operated with skip car; 1 ash gathering car, motor driven; 1 coke dust conveyor, from breeze pit, 24″ belt; 1 coke dust conveyor for distributing dust to bins on boilers, 24″ belt.

Power House.

Two (2) 500 KW turbine driven, 6600 volt, alternators, 1500 R.P.M., 25 cycle, 3 phase, with barometric condensers; one 150 KW turbine driven exciter, 250 volts, 750 R.P.M., turbine speed 7260 R.P.M., floating reduction gear; one 150 KW motor driven exciter, 250 volts, 750 R.P.M.; 1 complete oil filtering system for turbines; 2 air washing systems for generators; one 14 KW motor generator set for control circuits; three 200 KVA power transformers, 6600-220 volt; three 25 KVA lighting transformers, 6600-220-110 volts; one 30-ton electric travelling crane.

Switchboard Equipment:—All oil and disconnecting switches and their conductors are enclosed in 84-foot brick cell structure; oil switches are magnetically operated from a desk section, 24′0″ long, on the balcony. Average load of Power House, 4000 KW per hour. Total connected load of plant, 16,000 H.P.

Sub Station.

Two (2) 750 KW, two bearing, motor generator set, 6600 volts A.C.-250 volts D.C.; three 800 KVA power

transformers, 6600 volts-220 volts; three 25 KVA lighting transformers, 6600-220 volts; switchboard, 54′0″ long; distributing panels; concrete cell structure, 28′ long.

Transformer Stations.

Three (3) transformer stations for A.C. current for coal hoist, coal conveyors, quenching pump motors.

Underground Conduits.

All conductors are lead encased and are run underground in fibre conduit and in concrete. 65,000 feet of lead encased cable were required. Total capacity 5500 KVA.

Oil House.

Building, 25′0″ wide by 80′0″ long. for oil, grease and waste; four 12,000 gallon oil tanks, for engine, valve, carbon and black oil; six 1000 gallon oil tanks, for turbine, compressor, motor, transformer and lard oil; four 170 gallon tanks for wood alcohol, turpentine, signal oil and linseed oil; one 550 gallon underground tank for motor benzol; 15 Bowser hand pumps; 3 waste bins, 600 pounds capacity.

Storeroom and Brick Shed.

Building 50′0″ wide by 340′0″ long, fireproof; storeroom office, storeroom equipment with steel shelving.

Fire Protection (Coke Works).

One brick building, 102′0″ wide, 220′0″ long, with two 1,500,000 gallons capacity per 24 hours, 230 pounds discharge pressure, 200 H.P. motor; twelve 2-way fire plugs.

MACHINE SHOP.

One brick building, 102′0″ wide, 220′0″ long, with two balconies; offices for Master Mechanic, Superintendent Electrical Department, Machine shop foreman. Equipment consists of the following:

1 30-ton electric travelling crane.
1 42″ engine lathe.
1 24″ engine lathe.

1 20″ engine lathe.
1 14″ engine lathe.
1 12″ engine lathe.
2 24″ crank shapers.
1 20″ crank shaper.
1 120-ton hydraulic wheel press.
1 60″ gear cutter.
1 48″ openside planer.
1 6′0″ boring mill.
1 locomotive repair pit.
1 42″ milling machine.
1 key way milling machine.
1 6′0″ radial drill press.
1 4′0″ radial drill press.
1 25″ drill press.
1 21″ drill press.
1 power cold saw.
1 hack saw.
1 key seater.
2 emery wheels.
1 2-stage air compressor.

Tool Room.

1 28″ milling machine.
1 20″ crank shaper.
1 14″ engine lathe.
1 tool cutter and grinding machine.
1 21″ drill press.
1 12″ emery wheel.

Blacksmith Shop.

1 1500-lb. pneumatic forging hammer.
3 down draft forges.
1 heating furnace.
1 4-ton jib crane.

Boiler Shop.

1 double punch and shear.
2 2-ton jib cranes.

Office Building.

One (1) fireproof office and laboratory building, 52′6″ wide, 141′2″ long.

Telephone System.

One (1) complete telephone system with 60 stations.

Sanitary Stations.

Eight (8) complete sanitary stations, equipped with toilets, locker rooms, lockers, shower baths, for all departments of plant.

Drinking Water System.

Three (3) deep well pumps, 50,000 gallons capacity each per 24 hours, for sanitary fountains throughout the plant.

Sewage Disposal Plant.

One (1) sewage disposal plant with sewage treating basins and separate sanitary sewer system.

River Wall.

A concrete river wall is constructed along the harbor line the entire frontage of the first 12 battery unit. Wall 51′0″ high, 2,063 feet long, total concrete 45,000 cubic yards, base of wall 25′0″ wide resting on wood piling 3′0″ centers driven to refusal.

SUPPLEMENT DEVELOPMENT IN CONNECTION WITH CLAIRTON BY-PRODUCT COKE WORKS.

Five hundred (500) modern dwelling houses, 4 to 9 rooms each, each equipped with furnace, running water, gas, electric light and bath. Five (5) boarding houses for accommodating a total of 128 men. Fifty (50) 3-room houses for colored families, each equipped with running water, gas, electric light and toilet. One (1) community laundry and bath house for colored families.

One (1) complete sewage disposal plant in connection with houses in Wilson Town Site.

One (1) 40″ diameter gas line, 8½ miles long, deliver-

ing gas to Duquesne, Edgar Thomson and Homestead, and one 30″ diameter gas line 6000 feet long delivering gas to Clairton Steel Works and Factories.

One (1) standard gage railroad, 8 miles long, connecting Clairton with Duquesne.

Five hundred (500) 100,000-lb. capacity steel hopper cars for coke shipments.

One (1) river transportation fleet consisting of the following craft: 120 steel barges, 27′0″ wide, 175′0″ long, having a capacity of 1,000 tons of coal, 9′0″ draft. Seven (7) towboats, six of the stern wheel type and one of the screw propeller type, each boat capable of handling six loaded barges to the tow. One (1) gasoline tug for spotting barges in front of hoist and assembling empties. One (1) bulldozer, and one (1) ice breaker.

A concrete river wall along the harbor line for the entire frontage of 12 additional battery units. Length of wall 3,250 feet.

The complete plant at Clairton will probably consist of 24 batteries; 12 batteries, or 50%, as described above, with all the necessary equipment are completed and in operation.

One 250,000-ton capacity coal storage, for storing coal from barges,—equipped with one (1) gantry crane with two 5-ton buckets, 400′0″ span, with 85′0″ overhang on either side.

Mr. Marquard illustrated his paper by moving pictures and stereopticon.

At the close of Mr. Marquard's address, Mr. Schwab requested Mr. John A. Topping to take the chair.

Vice-President Topping: Gentlemen, aside from the wonderful pictures and the lecture of Mr. Marquard, the interesting thing to most of us would be the thought that we have made an effort toward economy as suggested by these pictures; instead of wasting millions of money in raw materials and natural resources, we are going to conserve and save them hereafter.

The next very interesting paper will be by Mr. F. T. Llewellyn on Standardization of Ship Materials.

Mr. F. T. Llewellyn: Mr. Chairman and gentlemen, in expressing appreciation of this opportunity to appear before the Institute, I would hasten to assure you that I am not going to read my paper in full—for two reasons; in the first place, it is very long; and in the second place, a large part of it is made up of tables, which I think will be of interest to study, but would be very monotonous if read. Instead, with your permission, Mr. Chairman, I will try to make a running comment on my paper, so that anybody who is interested in the subject may follow it more in detail when it is printed.

(The full text of Mr. Llewellyn's paper follows.—Ed.)

STANDARDIZATION OF SHIP MATERIALS

Fred T. Llewellyn

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1.* It will be the aim in this paper to present a brief outline of the need, history, and possibilities of standardization in connection with some of the materials used in the construction and equipment of steel cargo ships. The paper is supplemented by five appendices, which will not be read, but whose examination, it is believed, will support the conclusions reached.

2. For all practical purposes "standardization" does not mean "making everything alike"—that is "imitation." The term signifies rather "regulation in accordance with a series of common criteria," and the efficiency of the standardization varies inversely with the profusion of the criteria and directly as the breadth of their applicability. There are at least three different phases of standardization as applied to ships—standardization of types, which is largely the owner's or operator's affair; standardization of designs, in which the shipbuilder is principally concerned; and standardization of materials, which is most vital to the manufacturer—and while all three phases are to some extent inter-related it is desirable not to confuse their respective scopes. The possibilities of standardizing the various types of ships may be limited by differing conditions of routes, harbors, and service, but standard ranges and grades of material can be applied to any ordinary types and designs. The present paper will confine itself to the standardization of ship *materials,* referring to the type or design of ships only in so far as the standardization of their materials may be affected thereby.

3. It is impossible here, nor is the writer competent,

* The numerals before paragraphs refer to the Synopsis, see page 229.

to discuss in detail the multitude of different kinds of material that enter into the construction and equipment of a ship, but some idea of their variety may be obtained from Appendices A and B, in which are given tentative classifications respectively of ship parts and of ship materials. Appendix C suggests a series of topics under which investigations into the standardization of such material might be conveniently grouped. While these three appendices should not be considered other than suggestive, they represent considerable investigation, and in addition to the information given they may afford a convenient series of pigeon-holes for the classification of additional data. Some standardization of miscellaneous parts has already been accomplished, as in the case of chain, anchors, lifeboats, hardware, and other parts, but it is believed the field offers opportunity for further work along the line of the plain materials and equipment used. Possibly such investigation might come within the scope of the American Society for Testing Materials. If there are present manufacturers of engines, pumps, or other auxiliaries, they are invited to consider whether it should be necessary for the buyer of a ship, desirous of having her parts interchangeable, to restrict his purchases to the product of one maker.

4. While steel is only one of the many materials needed in shipbuilding, and while there are numerous steel products required in addition to those in the hull structure, yet the hull structure is so important, constituting as it does some 75 per cent. of the weight and 50 per cent. of the cost of a cargo ship, and its materials are of such special concern to the American Iron and Steel Institute, that the body of this paper will be devoted to that portion of the subject.

5. Let us first consider the opportunities for the standardization of hull steel as compared with other fields in which structural steel is used. While in some respects the requirements of a ship resemble those of rolling-stock, comparison with bridge building practice seems to

offer the more practical appeal. A ship is a storm-tossed box-girder, a freight tank, a power-house, and a floating hotel, all combined. The popular notion that her stresses are indeterminate is no more correct than in the case of fixed steel structures. The origin of design in both classes of structures was an accumulation of empirical rules, and in both cases theory has simply afforded an intelligent means of predicting the probable safety of an untried design from one whose behavior is known. The Titanic is matched by the Tay and the Quebec bridges.

The design of a ship indeed has some advantages over that of a bridge. When once built the bridge is largely left to the mercy of the elements (and of constantly increasing train loads), whereas on each voyage the captain of a ship has it within his power to stow and navigate in such a manner as to minimize the menace of the waves. It is of course true that this menace may reduce the safety factor of ignorance to a greater extent than in the case of a bridge.

The naval architect is also fortunate in that a large percentage of his loads are carried directly by the upward reactions due to buoyancy at different cross sections of the ship. Roughly speaking, the maximum longitudinal bending moment amidships is only about one-fourth the moment that would be caused by the uniformly distributed weight of ship and contents on a clear span equal to the ship's length; but this ratio does not hold at other points fore and aft.

If the inquisitive bridge engineer wishes to compare the accepted method of computing the principal stresses in a ship with his own theory of wheel loads, he has merely to lay off a trochoidal wave whose length equals that of the ship, and whose depth is one-twentieth thereof, and to correlate the severest possible conditions of loading with those of buoyancy under hogging or sagging (as calculated with the aid of Tchebycheff's Rule), when the maximum longitudinal bending moment at any point can be readily determined and compared with the section

modulus there; but the process is tedious. The transverse and local strains are similarly subject to computation by the enterprising mathematician. The dynamic stresses are more elusive.

6. The Classification Societies, realizing that dangerous errors, due to inexperience, oversight, or (in rare cases) unscrupulousness, might accompany the preparation of stress diagrams for each design, have saved the purchaser and the shipbuilder the time and labor that such calculations would require by publishing tabulated rules giving the scantlings recommended for the various hull members in ships of the more usual types and dimensions. These rules are revised from time to time in line with experience based on the constant survey of both the construction and operation of ships. It is to be regretted, however, that the eight principal classification societies have not as yet agreed among themselves on a standard set of rules.

7. The authority of the better known societies is justly great, but emphasis should be laid on the fact that classification is not refused for variation from their rules provided the substitutions are equally efficient; and this privilege broadens the possibilities for standardizing ship materials. For example, practically nowhere in a ship do the members that constitute the framing consist merely of single rolled steel shapes, for while they may appear to do so it will be noted that one or both of their flanges unite with the heavy plating of the shell, deck, or double-bottom tank-top strakes, or of the bulkheads, to form compound members wherein the plating is generally the most active element, on much the same principle as that followed in ferro-concrete construction, where a part of the floor-slab is utilized as the compression flange of a Tee beam or girder. This arrangement permits of substitutions in the size and thickness of the elements in such compound members, for undesirable variations from the adopted standard range of shapes can frequently be avoided by modifying the plate thickness, and vice versa.

8a. On the other hand the possibilities for standardizing ship as compared with bridge material are limited by several considerations. With a given fuel consumption, the earning capacity of ships of similar construction and equipment varies with the ratio between the weight of water displaced by the loaded ship and that of the ship when empty. Consequently any excess weight, added with a view of standardizing material, not only may increase the first cost, which is not the most important factor, but will certainly decrease her earning capacity during the entire life of the ship. The theoretical soundness of this argument, however, seems to have been greatly overworked, for it has been found that the material in a given design can be standardized without adding over one per cent. (and usually very much less) to the total weight, and that a new design using standard material can in some cases be so arranged as to actually effect a saving in the quantity used.

8b. The essential requirement of water and oil-tightness also affects the determination of suitable material. In a bridge the main criterion is usually that of strength alone, but in a ship local stiffness against deflection is just as important in order to prevent leaks resulting from an opening up of the joints. Also, in order to assist tightness, in shipbuilding single rolled steel angles are preferred to the pair of angles so dear to the bridge builder, for the single angle is more readily caulked, and its use minimizes those opportunities for corrosion that are invited by the concealed pockets between the heels of a pair of angles. The need of watertightness also causes the ship designer to avoid 3-ply rivets (*i. e.,* rivets connecting three thicknesses of metal) as far as possible, for it is difficult to ensure the efficiency of such rivets, or to locate the source of a leak at such connections. Therefore 2-ply rivets are used wherever practicable, and this means that instead of concentrating a number of connections at one point or line, in shipbuilding the important joints are arranged to come off center, or staggered.

The local stresses caused by this eccentricity are more than offset by its many advantages.

8c. Similar considerations explain in part the unsuitability for shipbuilding of standard structural channels less than 15 inches in depth, for their flanges are too narrow to receive the proper sized rivet hole, and their inner faces too steep to allow of a symmetrical rivet head, and the proximity of the rivet head to the fillet of the channel makes efficient laying-up very difficult. For this reason ship channels, having wide flanges with almost flat inner faces, are preferable for medium sized ship members, and bulb angles for the smaller ones. A bulb angle is stronger than a plain angle of equal weight; it can be readily manipulated on the bending slabs; and the mass of metal forming its bulb is a protection against the wear and tear of such cargoes as coal, ore, or steel. The bulb offers only a small surface to corrosion, and unlike the flange it is never in the way of riveting.

8d. While recognizing the advantage of Tees in facilitating the making of water and oil-tight connections, notably at the bulkheads of Isherwood tankers, as well as in the construction of bilge keels, the total demand for these sections as compared with the variety of contours offered by the few mills rolling them is insufficient to warrant their general use. Similar objections apply to the occasional specification of Zees. The popularity of "H" sections for use as pillars has been limited to a comparatively small number of yards, and the writer is not familiar with any difficulty in obtaining them, but the fact that the larger sizes are produced by only one mill, and the difficulty of making substitution in case of need, has made it desirable to generally refrain from their use, and this was apparently realized by the shipyards affiliated with the aforesaid mill. The symmetrical properties of the "I" beam, which is so popular in steel bridges, buildings, and cars, make this shape inefficient and wasteful in the compound members of which a ship's framing is necessarily composed, and it may be excluded from consideration for the purposes of this paper.

8e. A semi-medieval custom, whose effect is not always realized, has tended to befog the steel engineer in his efforts to clarify the application to ships of his experience in other structural lines, namely the terminology employed. This is due not so much to the use by shipbuilders of special terms (for who would rob the seafaring man of his picturesque phraseology?), but rather to the employment by both ship and bridge builders of common terms but with different meaning, and of different terms with the same meaning. Thus, the "deadweight" of a ship is the "live load" on a bridge. The structural engineer would call the "floors" of a ship "floor girders," while *his* "floors" are known in a shipyard as "decks." The "web-frames" of a ship correspond to bridge "portals," her "cant-frames" to "skew-portals," and her "bulkheads" to "diaphragms." The "foundations" beneath a ship's machinery would be known on land rather as "grillage," while a marine "erection" is confined to "superstructure." The shipbuilder usually restricts the terms "gusset" plate and "stringer" to horizontal members, preferring the respective terms "bracket" and "girder" if they are vertical, and plain rolled steel "angles" are not classed as "shapes" in the older shipyards, whereas rolled steel "bars" are frequently so included. The "shell" of a ship might be termed "skin" by a structural engineer, who would "furnish" or "attach" members that in ship parlance are "fitted," and he would put a "crimp" in plates or frames that on the ways are "joggled." In those rare cases when bridge or building connections have to be made from field templates they are said to be "Manley'd" by our biggest fabricator, whereas on a hull they are "lifted" from the frames.

9. In spite of these unknown tongues, it will be evident that the material used is the distinguishing factor in the differing conditions of design. In a ship the plates (which make up some two-thirds of her tank-like hull structure) are the all-important element, the shapes serv-

ing merely to brace and locally reinforce the plating; whereas in a bridge or building the shapes preponderate as the nucleus of its skeleton framework, plates being used in large measure merely to unite and reinforce the shapes.

10. Some old line shipbuilders have argued that the cost of the plain material in a ship is a comparatively small percentage of the finished hull, and that the need for standardizing ship materials is therefore not so urgent. Such an argument overlooks the most vital aim of standardization, which is to increase production by simplifying all the processes involved—at the rolling mill, in the shop, and on the ways—although as regards material cost alone it is reasonable to believe that in the long run better terms, as well as service, may be procurable from the rolling mills for a tonnage that is attractive from the standpoint of mill operation, as opposed to one requiring too frequent roll changes or other irksome features.

11a. That such standardization was necessary in order to successfully carry out the enlarged shipbuilding program which formed perhaps the keystone of this country's contribution to the War, and which is expected to continue on a scale undreamed of a few years ago, is evident from the following facts. Rolled steel plates were being ordered in at least three different and non-interchangeable ways, some specifications giving weights per square foot, some giving thicknesses in sixteenths, thirty-seconds or sixty-fourths of an inch, and some using the decimal system varying by even hundredths of an inch, the latter having partially replaced the old British use of twentieths of an inch. To further complicate matters our mills were simultaneously executing foreign orders based on the metric system. It frequently happened that the quantity required of some odd thickness was totally insufficient to warrant changing the rolls. While it is manifest that such variations are closer than it is feasible to produce on a commercial basis, and closer

even than the rolling mill tolerances permitted by the specifications, and while in many cases substitutions were, as a matter of fact, allowed after receipt of specifications by the mills, yet the confusion resulting from this meticulous attempt on paper to secure unnecessarily minute variations, especially when the tonnage was to be allocated through the War Industries Board, made it imperative that a simple and uniform range of thicknesses be adopted.

11b. Additional confusion and delay were being caused by the use of differing order forms and quality specifications, by the slowing down of the mills to shear to sketch awkward and irregular shaped web-plates, brackets and gussets (which usually had to be re-trimmed at the shipyard), and by the excessive quantity of hieroglyphic location marks that the mills were expected to paint on each plate, and which at times required more space than the surface of the smaller plates afforded.

11c. While the tonnage of rolled steel shapes required is only about one-half that of plates, the diversity of sections (see Appendix D) that were being specified by the seventy odd steel shipyards in this country, even when their ships were to the same design (see Appendix E), aggravated by the absence of uniformity between the steel makers in the contours of many of their sections, made the question of standard shapes equally important and much more of a task. The number of different shapes used reached the astounding total of 131, and the number of their different thicknesses 403, even when those thicknesses of the same shape that did not differ by more than 2½ per cent. were counted as the same section. In one hull, involving about 500 tons of shapes, there were 42 different sections and 118 distinct thicknesses, of which 9 sections were rolled only at one mill and one tee section at another mill. Of separate sections there were items as low as 8 lbs. per hull, and 35 thicknesses involved less than 500 lbs. each. Of one shape only 43 lbs. per hull were required. While many of these sec-

tions were for use in secondary members, their specification seriously hampered the mill in cleaning up orders.

11d. A comparatively small tonnage of rolled steel bars (other than rivet rods) is needed for each hull, mainly for use as liners or fillers, but here again minute variations in thickness and width, often required only to give a neater appearance, caused unwarranted difficulty in the complete shipment of the mill orders for any portion of a hull.

12. These were the factors responsible for the so-called "lag-lists." These were the odds and ends that threatened to render unavailing the strenuous efforts of the rolling mills to ship in sequence, and that encouraged an otherwise unnecessary "cushion" of reserve stock at one time aggregating over a million tons. These were the conditions that made it possible for one of our large shipyards to have received some 30,000 tons of steel without having on hand enough of the proper sizes to allow them to proceed with the construction of a single ship. The responsibility for these conditions was as usual divided, and need not be reviewed at this time. The important thing was to remedy the situation, and here again the credit should be divided, for it was only by the hearty co-operation of the Emergency Fleet Corporation, the steel makers, the fabricating shops, and the shipyards that a practical form of standardization was achieved.

13. Before narrating the steps taken in this country for such standardization, it should be stated that contemporary but independent action, with similar aim, was maturing in the British Isles, where the Admiralty, the steelmakers and the shipbuilders also realized the interference with ship production that resulted from a multiplicity of different sized material. Accordingly in December, 1917, a list of standard sections was drawn up and published under the joint auspices of the Admiralty and the Minister of Munitions, by the use of which regular and frequent rollings might be facilitated, and delays avoided. For cargo ships this list selected four sections

of plain angles, three of bulb angles, and two of ship channels, making a total of only nine sections in all. It should be noted, however, that as a result of the practice of the British mills to roll with much closer variations in thickness than we do, these nine sections gave the designer about as much latitude on paper as twenty-seven of ours.

14a. Although the opportunity to standardize the steel shapes used in shipbuilding in the United States did not fully materialize until after the British had acted, yet we beat them to it as regards plates. In July, 1917, representatives of our steel plate mills met in Washington and adopted an outline of recommended standard practice sponsored by Mr. R. B. Woodworth, Engineer with Carnegie Steel Co., and this was subsequently adopted by the Emergency Fleet Corporation as a guide to the shipbuilders in placing orders with the mills for ship steel. This recommended standard practice received such wide publicity in the pamphlet entitled "Structural Steel for Ships," that only its more salient features need be summarized here:—

Plates to be ordered to fractional thickness in multiples of 1/16 inch or to a table of weights corresponding approximately thereto, multiples of 1/32 inch being allowed in special cases.

Sketch plates to be sheared at the shipyards.

Universal mill plates to be used wherever possible.

Multiple lengths and widths to be allowed as far as practicable.

Extreme sizes to be avoided.

Specification of definite and uniform grades of steel.

Elimination of location marks on material as shipped from the mills.

The first edition of the above mentioned pamphlet also limited the list of plain angles recommended, and urged that orders for other shapes be confined to American standard "I" beam and structural channel sections, although it allowed the use of ship channels and bulb

angles in special cases. While it was recognized that ship channels and bulb angles were most suitable for shipbuilding, yet at that time the limited facilities in this country for their manufacture made it desirable to encourage the use of only such structural shapes as could be allocated to any steel maker. A complete selected list of structural sections seemed unnecessary in view of the Emergency Fleet Corporation's plan for the standardization of design.

14b. These standardized designs, however, failed to reduce the variety of sizes, especially in the so-called "fabricated" ships where it seemed as if bridge had been added to ship sections by the inability of the two classes of draftsmen to combine, and an excessive multiplicity of sections was the result. Also many yards continued to specify ship channels in such quantity that several steel makers who had not previously rolled them were arranging to produce these shapes, as well as bulb angles.

14c. Uniformity could be secured only by standardizing the range of sections to be rolled, and by the adoption of a selected list of sections to be specified. But who should say just which sections should be included in such a standard range and list? If predicated merely on the opinion of one investigator his judgment might well be challenged. It was evident that these standards, in order to carry weight, must be based on a survey, both broad and detailed, of the entire practice of all the shipbuilders in the country, and that the results must then be correlated with the productive capacity of all our rolling mills, modified where necessary to suit the most prevalent and warranted requirements of design and construction.

In August, 1918, such a survey was undertaken by the writer, who had been placed in charge of the Standardization of Ship Steel under Dr. H. C. Sadler, Naval Architect, by Mr. Daniel H. Cox, Manager of the Division of Steel Ship Construction, Emergency Fleet Corporation.

The starting point was the compilation and analysis of 84 classified summaries showing the quantity of each

thickness of every section used in each of the 44 designs to which the 1,508 ships canvassed were being built. As these ships had a total deadweight capacity of 10,302,150 tons, and involved 1,100,651 tons of steel shapes, their analyses might be considered representative. Most of the summaries were furnished by the 60 shipyards reporting, supplemented by compilations and weight extensions made from steel schedules and designs on hand at the home office of the Emergency Fleet Corporation. Sets of 52 large charts were prepared from these summaries, showing graphically the relative popularity of each section, and these were of value, not only as a basis for the recapitulations included in the formal report, but also, as the work progressed, to indicate the probable sections to be recommended, for simultaneously with the preparation of the data informal conferences were held with representatives of most of the rolling mills and of many fabricating shops and shipyards, who were thereby enabled to save time when later called upon for definite action. A total of over a quarter of a million figures were tabulated or otherwise handled, the time required for the preparation and issuance of the report being two months and one week, which was one week longer than promised on account of delay in securing data from a few of the nearby shipyards.

14d. On October 15, 1918, a report was submitted to the officials of the Emergency Fleet Corporation, in which the above outlined need of further standardization was supported by tabulated statistics, and a selected list of sections proposed, together with the recommendation that copies of the report be placed in the hands of all the interested steel makers and shipbuilders with a request for constructive comment and criticism. It was further recommended that, with the allowance of suitable time for the receipt and digestion of such comment and criticism, the steel makers represented by the American Iron and Steel Institute be invited to a conference in Philadelphia, there to confer among themselves and with

representatives of the Emergency Fleet Corporation with the view of modifying their rolls so as to produce like sections, and of publishing selected ranges of contours and weights thereof. Certain other detailed revision of the previously recommended standard practice was suggested with the view of making more uniform and efficient the methods of ordering ship steel, and it was finally recommended that the findings of this conference, upon approval, be made effective by the issuance of a formal order to the shipyards by the Emergency Fleet Corporation. No steel maker was asked to scrap any rolls or to prepare any new ones, as it was recognized that this was his own affair, but it was urged that a common standard be agreed upon with which such sections as each maker produced or contemplated should comply.

14e. Conformably with the invitation extended in accordance with this report, conferences were held at the offices of the Midvale Steel Corporation, Philadelphia, on November 19 and 20, 1918, which were attended by representatives of all the larger mills rolling structural steel shapes, namely, Bethlehem Steel Company, Cambria Steel Company, Carnegie Steel Company, Eastern Steel Company, Illinois Steel Company, Inland Steel Company, Jones & Laughlin Steel Company, Lackawanna Steel Company, Phoenix Iron Company, and Tennessee Coal, Iron & Railroad Company. The Vice Chairman of the Sub-Committee on Steel Distribution of the American Iron and Steel Institute, who had heartily co-operated in the proposed plan of standardization, was also represented, together with the Chief Designer of the Emergency Fleet Corporation, and the writer. Communications had meanwhile been received from other shape mills, as well as from a large number of the shipyards, advising their approval of the movement and submitting in detail many valuable suggestions.

The first day was occupied by the steel makers in technical discussion of the modifications necessary to standardize their shape rolls, and of the proposed selected

list of sections. In order to secure uniformity of action it was agreed that the detailed properties of the New American Standard Sections should be calculated by the Carnegie Steel Company and checked by the Cambria Steel Co. On the second day the findings of this conference, as regards the recommended standard practice, were submitted to the representatives of the Emergency Fleet Corporation, who, with a few minor modifications acceptable to the steel makers, approved them. The subsequent issuance by the Emergency Fleet Corporation of a second edition of the pamphlet entitled "Structural Steel for Ships," in which the revised recommended standard practice was adopted, the formal endorsement of the findings of the conference by the Association of American Steel Manufacturers, on February 21, 1919, and the general distribution by the steel makers of publications covering their new standard products, make it unnecessary to reprint the recommendations in this paper. It should be stated, however, that the variety of different shapes was reduced from 131 to 27, and of different thicknesses of sections from 403 to 115, and that the New American Standard Sections of ship channels and bulb angles were based on the British Standard Sections.

14f. In view of the fact that some misconception has existed regarding these New American Standard Sections a word of explanation seems to be in place. Prior to the action just narrated, the United States had no standards for the shapes in question—the shipbuilding demand had not warranted it. Instead there was a heterogeneous growth of sections whose profiles and weights differed with each mill, for which in many cases rolls had been turned up in periods of business depression to meet the desires of the various shipyards for something a little lighter than competitors were using. These sections were often too slender for economical manufacture, and offered no basis for standardization.

In the British Isles, however, where steel shipbuilding

had its cradle, and, until recently, its greatest development, the demand for suitable and uniform sections had made necessary the adoption of a series of standards. To this end, in 1904, an Engineering Standards Committee was appointed under the auspices of the British Institutions of Civil, Mechanical, and Electrical Engineers and of Naval Architects, as well as of the British Iron & Steel Institute, and this committee, after the most careful investigation, recommended for use in all these fields of engineering construction a series of standard sections that were acceptable to both makers and users, including the shipbuilding industry. These were called the British Standard Sections, and these are the sections on which are based the British bridge, building, and rolling-stock specifications, and the tabulated rules of the British ship classification societies, as well as those of our own American Bureau of Shipping. These rules and specifications we had not hitherto been able to satisfy except by frequent substitutions that involved a sacrifice of material and annoying changes in templates. The standards now forming a part of the recommended practice of American steel makers will, as far as they go, enable us to comply with the shipbuilding rules, and also more efficiently to take care of the export demand for rolled shapes regardless of their purpose. They are better adapted to economical manufacture than are our structural channels or the motley crowd of sections replaced. They should make for international comity by reducing to common terms the language of negotiation, even though it be combined with more effective competition.

To clearly understand the situation, however, it is important to remember that the practice of the British rolling mills differs from ours in that they roll to any thickness desired (usually by nominal steps of even hundredths of an inch), whereas we find it more profitable for the maker, and ultimately more serviceable to the user, to adopt a series of specific weights per lineal foot intermediate between the maximum and minimum. Con-

forming to foreign custom the tables of British Standard Sections publish only one standard thickness for each of the sizes of shapes in question, namely, the thickness at which the web and flange of the section are exactly the nominal dimensions of the shape, with an explanation that for other thicknesses these dimensions will vary with the desired squeezing or spreading of the rolls.

In order to secure the benefit of the British standards, and at the same time comply with the valuable practice of our United States mills, the New American Standards start out with the adoption of the British standard thickness of the section in question, and to this the rolls are cut. We then list one thickness five one-hundredths of an inch below, together with upper thicknesses generally varying in the ship channels by one-tenth of an inch, and in the bulb angles by five one-hundredths of an inch. These ranges take care of the lower thicknesses even more consistently than the tabulated rules of the classification societies, and they also cover all the upper thicknesses specified in the rules that seemed warranted by demand. It is believed that a scrutiny of these details will show the basis of the New American Standard Sections to have been warranted.

14g. Incidentally it should be remarked that several of these ship sections are popular also among manufacturers of rolling-stock in this country, and the suggestion is made that such manufacturers familiarize themselves with the changes adopted in the new standards. The modifications will not be inconvenient.

15a. It is a little early to speak of the full results of these steps toward standardization. Their primary purpose was to help win the War by assisting in the speeding up of the production, fabrication, and assembly of ship steel. And then came the unexpected armistice, which made less imperative the military features that had been aimed at. But any feeling of disappointment that these aims had been only partially realized at that time was more than compensated by relief at the saving of further

bloodshed and devastation. Moreover, all the details had been handled with an eye to future conditions of peace as well as those of the recent emergency. It is gratifying, however, to note that early in 1918 the industry was already benefiting from the degree of standardization then accomplished. As a result of the uniformity of specifications received, one of our newer plate mills, with a normal capacity of 12,500 tons per month, was enabled to increase its product to 16,000, 17,240, 18,025, 19,145, and even 20,973 tons per month.

15b. As regards shapes, the shipbuilders are substituting the standard sections now recommended as rapidly as the progress of their work will permit, and it has been possible by the elimination of odd sizes to design a 9400 ton ship with only 16 different shapes and 44 thicknesses of section, as opposed to the former averages of 28 shapes and 73 thicknesses per ship, and this was evidently accomplished without increase in weight of steel, for the builder asked no increase over the agreed price for the ships. In general it has been found that yards using the least variety of different sections show the greatest efficiency in the delivery of ships, while the performance of yards using a great variety is the least satisfactory in proportion to their total tonnage. As regards the shape mills, it is understood that, after cleaning up their partially filled orders, as soon as a set of rolls require redressing the grooves are being modified to suit the new standards for ship channels and bulb angles, some rolls being scrapped and some new ones prepared as a matter of operating convenience.

16. All of the efforts toward standardization were made from the broad standpoint of benefit to the whole country. Encouragement and co-operation were extended by the Government agencies, and by former competitors and associates alike, from the Chairman of the Committee on Steel Distribution of the American Iron & Steel Institute, and the high officials of many of the large shipbuilding companies, to the draftsmen in the yards

and the order clerks at the mills. It is hoped and believed that the steps taken will continue to assist the entire industry as long as the recommendations are consistently carried out, or until they are superseded by something better.

APPENDIX A

Tentative Classification of Steel Ship Parts.

Hull-Structure.	Hull-Engineering.
Hull-Accessories.	Propulsion.

Hull-Structure—

Main (primarily for hull strength).

Foundations and Local Reinforcement.

Secondary (not for hull strength, nor movable, nor machinery).

Hull-Accessories—

Fittings (non-structural metal, attached to hull).

Carpenter (rough woodwork, including hardware, forming permanent part of ship).

Joiner (finished woodwork, including hardware and glazing, forming permanent part of ship).

Coatings (attached to surfaces of hull structure, except insulation).

Equipment (for operation, but not propulsion, of ship, not attached to hull).

Furnishings (for welfare of ship's company, not permanently attached to hull).

Hull-Engineering—

(machinery other than that needed for propulsion).

Auxiliaries.

Communication.

Heating.

Refrigeration.

Plumbing (Fixtures).

Piping.

Propulsion—
(machinery needed to propel the ship).
Steam Production.
Main Machinery.
Auxiliaries.
Piping.

Detailed Classification

Hull Structure

MAIN

Keels—
(with Doublers and Buttstraps).
Flat.
Bar.
Bilge.

Keelsons—
(with Long'l. Angles and Clips).
Main.
Side.

Shell Plating (flat, or bent hot or cold)
(with Doublers and Buttstraps).
Garboard.
Bottom.
Bilge.
Side.
Sheer.
Counter.

Floors (with Brkts., Gussets and Clips)—
(i.e. Transverse Girders in Double Bottom).
Tight (incl. Fndn. Reinforcement, Sumps and Cofferdams).
Lightened.
Skeleton.
Deep.
Bilge Brackets.

Intercostals—

Double Bottom (incl. Fndn. Reinforcement, Sumps and Cofferdams).

Tank Top Plating—

(with Doublers and Buttstraps).

Rider Plates.

Inner Bottom.

Margin Plates.

Bulkheads (with Hor. and Vert. Stiffeners, and Brkts.)—

(for Hull Strength: Others listed under "Secondary").

Collision.

Hold.

Eng. & Fire Room.

After Peak (Stuffing Box).

Longitudinal.

Frames (with Brkts. and Clips)—

(Single, Reverse, Deep, Web: Plain, or Bent, hot or cold).

Transverse—

Side.

Deck.

Hatch-end Beams.

Half Beams.

Strong Beams—

Hold.

Machinery Space.

Panting Beams.

Hoist Beams

Longitudinal.

Cant.

Stringers (horizontal)—

(with Brackets, Clips and Angle Bars).

Side.

Panting.

Breast Hooks and Crutches.

Deck.

Expansion Trunks—

Shaft Alley—
(with Stiffeners).
Main.
Thrust Recess.
Stuffing Box Recess.

Pillars and Stanchions—
(with Connections).

Girders (vertical)—
Deck Pillar.
Cargo Hatches.
Eng. & Boiler Hatches.
Coal Hatches.
Other Deck Openings.

Deck Plating—
(with Stringers, Doublers, and Buttstraps).
Main.
Upper.
Shelter.
Bridge.
Poop.
Forecastle.
Flats (or list under "Secondary").

Stern Frame (with Conns.)—
(Forged Iron or Steel, or Cast Steel).

Stem—
Upper (Rolled and Bent).
Lower, or Fore-foot (Rolled and Bent, or Cast Steel).

Liners—
(Flat or Tapered. Stop Waters listed under "Coatings").

Rivets—
- Heads—
  - Pan.
  - Snap.
  - Countersunk.
- Points—
  - Hammered (Cone).
  - Snap.
  - Countersunk.
- Shanks—
  - Plain.
  - Swelled Neck.
  - Tap.

FOUNDATIONS AND LOCAL REINFORCEMENT FOR FITTINGS AND AUXILIARIES

Foundations—
- Boiler Saddles.
- Engine and Condenser.
- Thrust Bearing.
- Shaft Stools.

Local Reinforcement—
- Frames of Angles or other Shapes.
- Doubler Plates.
- Stanchions—
  - Fixed.
  - Movable.

SECONDARY

Engine and Boiler Casings (except Coamings).
Screen Bulkheads (Spectacle, between Eng. and Boil. Rooms).
End Bulkheads for Poop, Bridge, and Forecastle.
Deck Houses.
Other Minor Bulkheads.
Coal Bunkers and Trunks.
Bulwarks and Braces.
Tanks (other than Double Bottom).
Mezzanine Flats (over Eng. Room).

Swash Plates.
Chain Lockers.
Magazine and Ammunition Trunks.
Vent, Light, and Access Trunks.
Companion Hatches.
Skylight Framing.
Pipe Casings.
Boat Scaffolds (if metal).
Cargo Battens (if steel).
Moulding and Chafing Irons.
Gun Platforms.

Note. Floor Framing and Checkered Floor Plating, Gratings and Railings for Eng. and Fire Rooms listed under "Propulsion."

Hull Accessories

FITTINGS

Access—

- Steel Doors and Ports (Sliding W. T. Doors listed under "Hull Engineering").
- Wire Mesh Doors and Gates.
- Hatch Covers (metal work).
- Manholes, Covers, Scuttles and Freeing Ports.
- Sidelights.
- Fixed Ladders and Companion Ways.
- Stack Lookouts, fore and aft.
- Gratings (but not in Eng. and Fire Room)—
  - Plain.
  - Patent.

Handling Cargo—

- Derrick Steps and Partners.
- Masts—
  - Cargo only.
  - Ventilator.
- Booms.
- Cleats, Eyeplates, and Ringbolts.

Davits—
- Lifeboat.
- Anchor.
- Ladder.

Rudder (Plate, Cast, or Fabricated)—
- Stock (Upper and Lower).
- Arms.
- Plate.
- Filling.

Handling Ship—
- Hawse and Chain Pipes.
- Hawse Flaps.
- Bitts, Chocks, Fairleads, and Mooring Pipes.
- Lugs for Propeller Tackle.

Ventilation—
- Airports and Ducts
- Ventilators (see also Masts, above).
- Skylight Gear.

Other Fittings—
- Railings (if metal, incl. Brass Rail around Compass)—
- Awning Supports.
- Fire Plugs.
- Scuppers and Drains.
- Metal Name and Draft Figures.
- Lockers (if metal, and built-in).

CARPENTER WORK

Caulked Decks.
Railings and Fenders.
Hatch Covers (woodwork).
Bed pieces and Packing.
Cargo Battens (if wood).
Ceiling in Bilges and Holds.
Pipe Casings.
Skids and Brows.
Boat Chocks, Ridgepoles, and Strongbacks.
Chests for Deck Gear.

Hawse Bucklers.
Boom Crutches.
Racks and Stowage for Life Preservers and Buoys.
Racks for Fire Hose.
Leadman's Platform.
Hardware.

JOINER WORK

Joiner Decks and Floors.
Bridge and Weather Rails.
Wood Houses.
Ceiling—
    Overhead and Beam Capping (under exposed decks).
    Side and Airport Trim.
Joiner Bulkheads and Partitions.
Wood Doors (and Screens)—
    Outside and Inside.
Windows (and Screens).
Boxes, Board and Screens for Side and Running Lights.
Stairways, Stairs, and Wood Ladders.
Wood Grab Rails.
Wood Skylights and Vent Trunks.
Inside Finish for all Rooms (List?).
Fixed Furnishings—
    Bath, Toilet and Wash Rooms.
    Saloon and Mess Rooms.
    Hospital.
    Galley and Pantries.
    Cold Storage Room.
    Storerooms.
Shelving.
Wood Gratings.
Hardware.
Glazing.

COATINGS

Cementing.
Bituminous Coatings.
Stop Waters.
Painting Hull.

Painting and Finished Joiner Work.
Tiling, Linoleum, and Floor Composition.
Name, Draft Figures, and Marking.

EQUIPMENT

Tackle (with Fittings)—
- Inboard—
  - Cargo (Stays and Running).
  - Boat and Raft (Guys and Running).
  - Stack Guys.
  - Flag (Running).
  - Comp. Ladder (Running).
  - Anchor (Running).
  - Blocks.
- Outboard—
  - Anchors.
  - Chains (incl. Spares).
  - Cables.
  - Hawsers.
  - Warps.
  - Leadman's Gear.

Life Saving—
- Boats, Rafts, with Equipment.
- Preservers.
- Buoys (complete).
- Fire Hose.
- Rockets (or equivalent) with Lines Complete.

Fire Protection (see also "Hull Engineering—Int. Communication and Piping")—
- Buckets and Axes.
- Hose and Reels.
- Extinguishers.

Storm Oil—

Nautical Outfit—
- Compass and Binnacle.
- Chronometer and Clocks.
- Lead Lines.

Log, with Book and Slate.
Barometer.
Drawing Instruments.
Flags and Signals.
Signal and Search Lights.
Submarine Sounding Machine.
Ship's Bells.
Fog Horn and Whistle.

Portable Fenders—

Canvas Work—

Awnings.
Tarpaulins.
Other Covers (except Hull Surface Coatings).

Accommodations and Ladders (if portable)—

FURNISHINGS

Furniture—

Wood—
Tables and Decks.
Chairs, Stools and Benches.
Lockers and Medicine Chests.
Berths.
Dressers and Mirrors.
Towel and Toilet Racks.

Metal—
Berths and Spring Mattresses.
Lockers and Safes (if movable).

Dry Goods—
Carpets, Rugs and Upholstery.
Curtains and Shades.
Mattresses and Pillows.
Napery—
Sheets and Pillow Cases.
Table Cloths and Napkins.
Towels.
Blankets and Counterpanes.

Outfits—
- Deck.
- Carpenter.
- Lamp.
- Paint and Oil.
- Galley Range with Outfit.
- Pantry and Galley.
- Mess.
- Amusement.

Consumable Stores—
- Steward's Deck Allowance.

Hull Engineering

AUXILIARIES

Handling—
- Ship—
  - (Rudder listed under "Hull-Fittings").
  - Windlass (with Chain Stopper).
  - Capstan (or Warp Winches).
  - Steering Engine (with Gear and Details).
- Cargo—
  - Hoisting Engines (Winches)—
    - Nigger Heads.
    - Extended Shafts.
  - Cargo Oil Pumps.
- Water—
  - Salt—
    - Fire and Bilge Pumps.
    - Ballast Pumps.
    - Sanitary Pumps.
  - Fresh—
    - Fresh Water Pumps.
- Ashes—
  - Ash Handling Gear (complete).

Electric—
- Generator (with Engine).
- Storage Battery.

Switchboards.
Wiring (with Conduits).
Lighting Fixtures (incl. Arc).
Instruments.
Motors.
Fans.

COMMUNICATION

External—
Wireless Outfit.
(other parts listed under "Hull-Equipment").

Internal—
Fire Alarm.
Directing Indicator.
Telegraphs.
Telephones.
Voice Tubes.

Heating—
Radiators.

Refrigeration Machinery.

Plumbing Fixtures.

Spares.

Tools.

Pipe and Fittings (with Traps, Valves and Manifolds, and Insulated Covering)—
Steam.
Water—
Salt.
Fresh.
Oil—
Fuel.
Cargo.
Lubricating.
Air.

Propulsion

STEAM PRODUCTION

Main Boilers (Scotch Marine)—
- Shell (with Doublers and Connections).
- Flanged Heads.
- Girders.
- Combustion Chamber.
- Furnaces.
- Tubes and Flues (with Ferrules).
- Retarders.
- Stays (with Washers and Nuts).
- Braces.
- Crown Bars.
- Rivets.

- Fittings—
  - Internal—
    - Dry Pipe.
    - Feed Pipes.
    - Other Pipes to Valves.
    - Hydrokineters.
    - Circulators.
    - Fusible Plugs.
  - External—
    - Manholes (with Covers).
    - Valves—
      - Safety.
      - Stop.
      - Check.
    - Blows—
      - Surface.
      - Bottom.
    - Salinometer Cocks.
  - Furnace—
    - Coal—
      - Fronts.
      - Bridge Walls.

Bearing Bars.
Grates.
Fire Brick and Clay.
Oil—
Fronts.
Nozzles and Burners.
Air Registers.
Fire Brick and Clay.
Superheaters.
Mech. Stokers.
Fastenings.
Draft (Fans listed under "Hull Eng.-Electric")—
Ducts.

Donkey Boilers (complete).

Uptakes.

Stacks (with Air Casings and Capes).

Lagging and Covering (excl. Pipes).
(Ash Handling Gear listed under "Hull-Engineering").

MAIN MACHINERY

Main Engines—
Stationary—
Bed Plate and Main Bearings.
Columns and Crosshead Guides.
Cylinders with Liner and Covers.
Valve Chest with Liners and Covers.
Steam Receivers.
Drains.
Stuffing Boxes.
Cylinder Lagging and Covering.
Moving—
Valves with Stems and Gear.
Pistons with Rods.
Crosshead.
Connecting Rod.
Crank Shaft.
Eccentrics with Rods and Straps.

Links with Blocks (incl. Suspension).
Rocker Shaft and Arms.
Attached—
Reversing Engine and Gear.
Turning Gear.
Handling Gear.
Indicator Gear.
Levers and Links for Attached Pumps.
Throttle Valve and Gear.

Oil Engines—
Main Units.
Electric Sets.

Main Turbines—
Cylinder and Rotor.
Transmission—
Reducing Gear.
Electric.
Attached.
Reversing.

Main Condenser.

Lifting Gear.

Shafting (with Flanges, Bolts, and Composition Sleeves)—
Thrust.
Line.
Tail—
Nut.

Shaft Bearing—
Thrust—
Horseshoe.
Kingsbury.
Steady.
Stern Tube.

Bearing Metal.

Lubrication—
Cups.

Propeller—
- Solid.
- Detachable Blade.

AUXILIARIES

Aux. Condenser.

Tanks—
- Feed.
- Filter.
- Inspection.
- Oil.
- Waste Lockers.

Oil Filter.

Feed Water Heater.

Fuel Oil Heater.

Evaporator.

Distiller.

Pumps—
- Fuel Oil Transfer.
- Fuel Oil Service.
- Main Feed.
- Aux. Feed.
- Evaporator Feed.
- Main Circulating (with Engine).
- Main Air.
- Combined Air and Circulating.
- Lubricating Oil.
- Oil Cooler.

Injectors (or list under "Boilers").

Sea Connections.

Overboard Connections.

Eng. and Boiler Room Structural—
- Framing.
- Checkered Floor Plates.

Gratings.
Handrails.
Guards and Pans.

Workshop and Storeroom—

Fire Room Spares.
Fire Room Tools.
Eng. Room Spares.
Eng. Room Tools.
Aux. Spares.
Consumable Stores.

Pipe and Fittings (with Traps, Valves and Manifolds, and Insulated Covering)—

Steam.
Water—
  Salt.
  Fresh.
Oil—
  Fuel.
  Cargo.
  Lubricating.
Air.

APPENDIX B

Tentative Classification of Materials

MAIN HEADINGS

Steel Rolling Mill Products—

Semi-finished.
Plates.
Shapes.
Bars.
Bands.
Hoops.
Sheets.

Tubular Steel Products—

Pipe.
Tubes.
Fittings.
Rods.
Wire.
Shafting.

Steel Wire Products—

Wire Rope.
Springs.
Miscellaneous.

Steel War Products.

Cast Steel Products.

Cast Iron Products.

Forged Steel (or Iron) Products.

Raw Ferrous Materials and By-Products—

Ore.
Pig.
Cement.
Slag.
Coal.
Tar.
Coal Gas.

Fabricated Steel Products.

Non-Ferrous Metallic Products—

Lead.
Tin.
Antimony.
Quicksilver.
Zinc.
Silver.
Copper.
Alloys.

Non-Metallic Products—
- Quarried.
- Oils.
- Ligneous.
- Refractory.
- Glass.
- Ceramic.
- Fibrous.

Detailed Classification

STEEL ROLLING MILL PRODUCTS

Semi-finished—
- Blooms.
- Billets.
- Slabs.
- Rods.

Plates—
- Sheared—
  - Wide or Narrow.
  - Rectangular, Taper, or Sketch.
- Universal—
  - Sheared Ends.
  - Cold Sawed Ends.
- Checkered.
- Skelp.
- Grades—
  - Hull—
    - Ordinary.
    - Flanging—
      - Hot.
      - Cold.
    - High Tensile.
  - Tank—
    - Ordinary.
    - Soft (for bending).
  - Boiler—
    - U. S. Steamboat Inspn.—
      - Shell.
      - Furnace.

Flange.
Tank.

Shapes—

Channels—
Ship.
Structural.
Angles—
Plain—
Structural Sizes.
Bar Sizes.
Bulb.
Tees—
Plain.
Bulb (Bulb Beams).
Bulb Bars.
"I" Beams—
Standard.
Thin Web.
Wide Flange.
"H" Beams—
8 inch and under.
Over 8 inch.
Zees—
Standard.
Hatch Section (Tyzack).
Sash.
Grades (same as Hull & Tank Plates).

Bars—

Square—
Plain.
Twisted.
Round.
Half-round—
Solid.
Hollow.
Flat—
Square Edge.

Oval Edge.
Strip.
Deformed.
Grades—
Rivet—
Hull.
Boiler.
Stay—
Longitudinal.
Combustion.
Chain.
Cutlery.
Alloy.
Others (same as Plates).

Bands—
Finish—
Black.
Galvanized.

Hoops—
Finish—
Black.
Galvanized.

Sheets—
Grades—
Ordinary.
Special.
Alloy.
Finish—
Black.
Galvanized.
Tinned.

TUBULAR STEEL PRODUCTS

Pipe—
Structural—
Pillars and Stanchions.
Davits.

Masts and Booms.
Ventilators.
Scuppers.
Railing.
Awning Supports.
Skylight Gear.
Berths.
Finish—
Black.
Galvanized.
Sherrardized.
Internal Pressure—
Air.
Steam.
Water—
Salt.
Fresh.
Oil—
Fuel.
Cargo.
Lubricating.
Glycerine.
Ammonia.
Gases.
Grades—
Lapweld.
Buttweld.
Finish—
Black.
Galvanized.

Tubes—
Internal Pressure—
Water Tube Boiler.
External Pressure—
Fire Tube Boiler.
Stay.
Flue.

- Grades—
  - Seamless.
  - Lapweld.

Fittings—
- Joint.
- Valve.
- Grades.
- Finish—
  - Black.
  - Galvanized.
  - Sherrardized.

STEEL WIRE PRODUCTS

Rods—
- Hot Rolled (for further manufacture).

Shafting (small sizes)—
- Cold Drawn and Cold Rolled.

Wire—
- Shape—
  - Round.
  - Flat.
- Grades—
  - Basic O. H.
  - Bessemer.
- Finish—
  - Bright.
  - Galvanized
  - Tinned.

Wire Rope—
- Outboard—
  - Towing Hawsers.
  - Mooring Lines.
- Inboard—
  - Rigging.
  - Hoisting.
- Fittings—
  - Hooks.

Sockets.
Shackles.
Turnbuckles.
Blocks.
Finish—
Bright.
Galvanized.
Fiber-clad.

Springs—
Extension.
Compression.
Torsion.

Wire Screens.

Nails.

Spikes.

STEEL WAR PRODUCTS

Plates—
Armor.
Protective Deck.

Guns.

CAST STEEL PRODUCTS

Lower Stem (Forefoot)—

Stern Frame—

Rudder—
Solid, or Stock and Arms.

Anchors—

Stud Chain (Electric Steel)—

Machinery Parts—

Finish—

CAST IRON PRODUCTS

Propeller—

Stern Tube—

Hull Fittings and Furnishings—

Machinery Parts—

Finish—

FORGED STEEL PRODUCTS

Stem—

Stern Frame—
(or Iron).

Rudder—
Stock (or Iron).
Arms (or Iron).

Anchors—

Line Shaft—

Machinery Parts—
(or Iron).

Discs—
Piston Heads.
Turbine Wheels.
Fly Wheels.
Pipe Flanges.

Chain—
Stud Link (or Iron)

Finish—

RAW FERROUS MATERIALS AND BY-PRODUCTS

Ore—
Red Oxide Paint.

Pig Iron—
For all Ferrous Products.

Cement—
Concrete.
Lining of Inner Bottom, and Decks.

Slag—
Concrete.
Mineral Wool.

Coal—
Fuel.
Carbons (Electrodes, Lamps, and Batteries).
Graphite (Paint, Lubrication, and Scale Remover).

Coke—
- Fillings.

Tar—
- Coatings.
- Benzene—
  - Dyes.
  - Motor Fuel.
- Toluol—
  - Signal Explosives, Dyes, Medicine.
- Naphtha—
  - Varnish, Paint, Stain, Linoleum.
- Carbolic Acid—
  - Disinfectants, Soap.
  - Bakelite—
    - Electric Insulation and Switches.
    - Varnishes.
    - Combs, Buttons.
- Lubricating Greases.
- Pitch—
  - Waterproofing, Asphalt, Paint.
  - Bitumastic Enamel, Solution, and Cement.
- Tarred Felt, Pipe Coatings.

Coal Gas—
- Ammonia—
  - Soaps.
  - Baking Powder.
  - Soldering.

Zinc—
- Plate and Fittings.
- White Paint.
- Sulphuric Acid—
  - Fire Extinguishers.

FABRICATED STEEL PRODUCTS

Parts—
- Structural.
- Rivets.
- Bolts.

Screws.
Hardware.
Boilers.
Furnaces.
Machinery.

Complete—

Ships.
Barges.
Boats.

NON-FERROUS METALLIC PRODUCTS

Lead—

Sheet.
Pipe.
Cast.
White Paint.
Red Paint.

Tin—

Antimony—

Quicksilver—

(largely for Anti-fouling Paint).

Zinc—

see By-Products.

Silver—

(for electroplating).

Copper—

Sheet.
Bar.
Pipe and Fittings.
Wire, incl. Insulation.
Tinned.

Alloys—

Bronze—
Manganese (Propeller and Antennae).
Tobin.

Other Compositions.

Brass—

Tubes (Condenser).

Pipe and Fittings.

Sheet.

Cast.

Hardware.

Instruments.

Solder—

Babbitt—

Magnesia—

Asbestos.

NON-METALLIC PRODUCTS

Quarried—

Slate.

Marble.

Grindstones.

Sand.

Clay.

Oils—

Crude.

Gasolene.

Lubricating.

Linseed.

Glycerine.

Ligneous—

Cedar.

Redwood.

Cypress.

Fir.

Elm.

Ash.

Pine—

White.

Yellow.

- Spruce.
- Oak.
- Lignum Vitae.
- Cork.
- Rubber.
- Rosin.
- Charcoal.

Refractory—
- Fire-brick.

Glass—
- Portholes.
- Skylights.
- Windows.
- Table.
- Bulbs.
- Instruments.

Ceramic—
- China.
- Crockery.
- Tiling.
- Enamel.

Fibrous—
- Manila (Rope).
- Hemp—
  - Cordage.
  - Gaskets.
  - Oakum.
- Cotton—
  - Twine.
  - Fabrics—
    - Canvas—
      - Deck.
      - Awnings.
      - Wick Stopwaters.
    - Flags.
- Furnishings (Linen, Wool, Hair, Felt).
- Kapok.

APPENDIX C

giving suggested topics to be considered in the further standardization of materials classified in Appendix B.

1. Each manufacturer should select the class of products in which he is interested, as applied to the parts classified in Appendix A, amplifying their subdivision as far as may be necessary to differentiate the essentials of each group.

2. A study should then be made, from the shipbuilder's standpoint, of the purpose for which, and the manner in which, each group of products is used, including storage and handling methods.

3. A study should also be made, from the manufacturer's standpoint, of the processes whereby each group of products is made, handled and shipped.

4. A further study should be made of any requirements or methods intermediate between manufacturer and shipbuilder, for example:—

- a. Materials handled by jobbers.
- b. Materials used by equipment makers.
- c. Transportation features.
- d. Patented products.

5. Suitable literature should be adopted or prepared for distribution throughout the organizations of manufacturer, intermediary, and shipbuilder, in which the results of the above mentioned studies are clearly explained and applied to such topics as the following:—

- a. General information regarding the ordering of each group of products in question.
- b. Number and kind of documents to be furnished by buyer to seller.
- c. Number and kind of documents to be furnished by seller to buyer, and where each should be sent.
- d. Form of lists, with typical illustrations.
- e. Desired time and sequence of shipment.
- f. Minimum unit quantities.

g. Sizes readily obtainable, including lengths.
h. Grades of material, i.e., to what specifications.
i. Allowable tolerances in manufacture.
j. Finish of material.
k. Accessories to be included.
l. Percentage of spares desired and allowed.
m. Branding and marking.
n. Inspection of material, i.e., by whom and where.
o. Packing.
p. Routing.
q. Guaranty.

6. It will be noted that the word "standard" does not appear in the above topics, but a reduction of the products thereunder to the fewest number of groups, common to the largest number of makers and users, should result in standardization that will enable the user to prepare his specifications so as to secure the most suitable material in the most convenient and economical form and with the least delay.

APPENDIX D

showing quantities (in short tons) of rolled steel shapes of various thicknesses specified for the 1508 hulls covered by Appendix E, tabulated by designs, shipyards, and hulls, with totals and averages.

Note. The normal popularity of bulb angles is not indicated by these tables, as their use had been restricted by the previously limited capacity for their production.

GRAND SUMMARY.

	Quantities	*Variety of Shapes*	*Variety of Sections*
Plain Angles—Equal Leg	330,600	14	66
" " —Unequal Leg	229,893	17	103
Bulb Angles (restricted use)	46,127	23	51
Ship Channels	405,545	16	55
Structural Channels	61,353	11	38
I Beams	13,857	23	30
H Pillars	5,492	7	38
Tees	6,330	13	13
Zees	1,454	7	9
	1,100,651	131	403

SUMMARY BY SHAPES.

Plain Angles—Equal Leg

Size	Quantity
8 x 8	2,280
6 x 6	41,554
5 x 5	32,889
4½ x 4½	70
4 x 4	15,023
3½ x 3½	166,332
3 x 3	65,510
2½ x 2½	5,984.5
2¼ x 2¼	6
2 x 2	827.5
1¾ x 1¾	76
1½ x 1½	47.7
1¼ x 1¼	0.5
1 x 1	0.2
14	330,600.4

Plain Angles—Unequal Leg

Size	Quantity
8 x 6	882
8 x 3½	11,750
7 x 3½	18,957
6 x 4	20,916
6 x 3½	52,011
5 x 4	994
5 x 3½	9,671
5 x 3	18,423
4½ x 3	257
4 x 3½	5,438
4 x 3	56,469
3½ x 3	26,019
3½ x 2½	2,780
3 x 2½	4,987
3 x 2	44
2½ x 2	289
2½ x 1½	6
17	229,893

Bulb Angles

Size	Quantity
10 x 3½	10,111
9 x 3½	4,906
8 x 3½	9,435
8 x 3	955
7½ x 3½	277
7½ x 3	0.2
7 x 3½	7,274
7 x 3	6,037.2
6½ x 3½	32
6½ x 3	0.2
6 x 3½	33
6 x 3	7,020
5½ x 3	32
5 x 2½	14
14	46,126.6
9	Extra Sets Rolls
23	

Ship Channels

Size	Quantity
12 x 4	31,270
12 x 3½	30,916
10 x 4	12,654
10 x 3½	51,622
10 x 3⅜	32,155
9 x 4	31,197
9 x 3½	104
8 x 3½	46,539
8 x 3	29
7 x 3½	35,780
7 x 3⅜	85,494
6 x 3⅝	316
6 x 3½	41,020
6 x 3	5,016
6 x 2½	1,373
4 x 2	60
16	405,545

Structural Channels

Size	Quantity
18 x 4	83
15 x 3½	15,785
13 x 4	3,053
12 x 3	28,890
10 x 2¾	1,147
9 x 2½	4,100
8 x 2⅜	6,603
7 x 2¼	1,221
6 x 2⅛	464
5 x 2	1
4 x 1⅝	6
11	61,353

I Beams

Size	Quantity
28 x 10	236
26 x 9½	582
24 x 9	4,565
24 x 7	916
20 x 7	189
20 x 6¼	133
18 x 11½	395
18 x 7½	1,827
18 x 7½	218
18 x 7	165
18 x 6	124
15 x 6¾	1,036
15 x 6	7
15 x 5½	2,374
12 x 5¼	628
12 x 5	200
10 x 4¾	101
9 x 4⅝	19
8 x 4	63
7 x 3¾	15
6 x 3⅜	55
5 x 3	1
4 x 2¾	8
23	13,857

SUMMARY BY SHAPES—*(cont'd)*

H Pillars

Size	*Quantity*
14	1,874
12	2,193
10	518
8	851
6	20
5	10
4	26
7	5,492

Tees

Size	*Quantity*
6½ x 6½	5,760
6 x 5¼	51
6 x 4½	77
6 x 4	101
5 x 3	81
4½ x 3	65
4 x 5	27
4 x 4	16
4 x 4	126
4 x 3	7
4 x 3	5
3½ x 3½	13
3 x 3	1
13	6,330

Zees

Size	*Quantity*
6	83
5	22
4	1
3	13
3	569
3	13
(Hatch) 2½	753
7	1,454

DISTRIBUTION

EQUAL LEG ANGLES

Size of Shapes	*Section Thickness*	*Wt. in pounds per ft.*	*Total Quantity Req'd*	*Used in* Designs	Yards	Hulls	*Average Quantity per Hull*
8 x 8	.75	38.9	227	2	2	32	7.1
	.6875	35.8	952	5	11	105	9.05
	.625	32.7	866	9	15	362	2.4
	.5625	29.6	9	1	1	10	0.9
	.50	26.4	226	5	6	370	0.6
			2,280	14	27	616	3.7
6 x 6	.875	33.1	5	1	1	5	1.0
	.8125	31.0	9	1	1	12	0.75
	.75	28.7	1,018	11	18	547	1.86
	.6875	26.5	1,115	4	3	125	8.9
	.625	24.2	5,389	19	31	769	7.0
	.5625	21.9	4,381	21	24	739	5.9
	.50	19.6	14,739	26	43	1,012	14.6
	.4375	17.2	13,071	27	52	1,094	11.9
	.375	14.9	1,822	19	33	904	2.0
	.3125	12.3	5	1	5	104	0.05
			41,554	31	52	1,448	28.7
5 x 5	.75	23.6	595	3	6	156	3.8
	.6875	21.8	492	6	11	122	4.03
	.625	20.0	3,322	14	31	759	4.4
	.5625	18.1	8,063	17	33	751	10.7
	.50	16.2	12,247	31	52	1,377	8.9
	.4375	14.3	7,031	25	42	1,176	6.0
	.375	12.3	1,139	17	35	826	1.38
			32,889	31	52	1,377	23.9
4½ x 4½	.625	17.8	70	1	1	10	7.0
4 x 4	.75	18.5	17	2	2	72	0.24
	.6875	17.1	975	6	10	258	3.8
	.625	15.7	1,966	13	17	415	4.75
	.5625	14.3	1,861	11	29	629	2.96
	.50	12.8	7,434	31	51	1,306	5.7
	.4375	11.3	1,984	24	36	870	2.3
	.375	9.8	769	20	33	801	0.96
	.3125	8.2	17	3	3	173	0.1
			15,023	31	55	1,442	10.4

EQUAL LEG ANGLES (Cont'd)

Size of Shapes	*Section Thickness*	*Wt. in pounds per ft.*	*Total Quantity Req'd*	*Used in Designs*	*Yards*	*Hulls*	*Average Quantity per Hull*
3½ x 3½	.75	16.0	173	2	1	180	0.96
	.6875	14.8	121	5	5	201	0.6
	.625	13.6	3,509	21	36	787	4.5
	.5625	12.4	5,629	17	27	589	9.6
	.50	11.1	36,427	32	54	1,314	27.7
	.4375	9.8	80,159	33	58	1,464	55.0
	.375	8.5	38,143	32	57	1,486	25.7
	.3125	7.2	591	13	26	615	0.96
	.25	5.8	1,580	2	2	80	19.7
			166,332	34	60	1,508	110.
3 x 3	.625	11.5	55	3	3	146	0.38
	.5625	10.4	367	5	5	226	1.62
	.50	9.4	3,964	24	46	1,101	3.6
	.4375	8.3	13,828	31	51	1,309	10.6
	.375	7.2	32,764	34	58	1,405	23.3
	.3125	6.1	5,864	30	52	1,276	4.6
	.25	4.9	8,668	9	15	551	15.7
			65,510	34	59	1,481	43.2
2½ x 2½	.50	7.7	3.5	1	1	70	0.05
	.4375	6.8	7	2	3	17	0.41
	.375	5.9	227	9	12	425	0.53
	.3125	5.0	3,587	27	59	1,358	2.64
	.25	4.1	2,128	25	46	1,138	1.87
	.1875	3.07	32	4	9	144	0.22
			5,984.5	33	60	1,406	4.25
2¼ x 2¼	.25	3.62	6	2	2	12	0.5
2 x 2	.375	4.7	11	3	4	75	0.15
	.3125	3.92	23	5	4	124	0.19
	.25	3.19	753	20	36	1,031	0.73
	.1875	2.44	40	6	6	170	0.24
	.125	1.65	0.5	1	1	10	0.05
			827.5	20	37	1,063	0.78
1¾ x 1¾	.375	4.1	10	1	5	104	0.1
	.1875	2.12	66	2	6	254	0.26
			76	2	6	254	0.3
1½ x 1½	.25	2.34	30	8	9	108	0.28
	.1875	1.8	17	6	6	101	0.17
	.125	1.23	0.7	3	3	124	.006
			47.7	12	16	301	0.16
1¼ x 1¼	.1875	1.48	0.5	1	1	2	0.25
1 x 1	.1875	1.16	.02	1	1	2	0.01

UNEQUAL LEG ANGLES

Size of Shapes	Section Thick-ness	Wt. in pounds per ft.	Total Quantity Req'd	Used in Designs	Yards	Hulls	Average Quantity per Hull
8 x 6	.75	33.8	32	2	3	34	0.94
	.6875	31.2	4	1	1	5	0.8
	.625	28.5	106	3	3	85	1.25
	.5625	25.7	28	3	7	179	0.16
	.50	23.0	387	7	14	508	0.76
	.4375	20.2	325	5	8	394	0.83
			882	12	18	567	1.5
8 x 3½	.75	27.5	1	1	1	2	0.5
	.6875	25.3	116	1	1	5	23.2
	.625	23.2	1,339	10	12	404	3.3
	.5625	21.0	3,152	2	1	180	17.5
	.50	18.7	5.076	12	20	592	8.6
	.4375	16.5	2,066	10	20	343	6.02
			11,750	17	31	723	16.2
7 x 3½	.875	28.7	99	1	1	110	0.9
	.75	24.9	1,765	4	10	235	7.5
	.6875	23.0	921	1	1	70	13.2
	.625	21.0	1,048	7	12	230	4.55
	.5625	19.1	75	3	4	37	2.03
	.50	17.0	5,791	13	23	744	7.8
	.4375	15.0	5,203	17	27	721	7.2
	.375	13.0	4,055	12	13	513	7.9
			18,957	29	44	1,142	16.5
6 x 4	1.00	30.6	1,758	5	13	152	11.5
	.9375	28.9	529	2	4	49	10.8
	.875	27.2	1,060	6	10	226	4.7
	.8125	25.4	3,760	6	13	153	24.6
	.75	23.6	2,552	8	15	239	10.7
	.6875	21.8	1,350	8	11	158	8.5
	.625	20.0	2,517	14	28	548	4.6
	.5625	18.1	2,156	11	24	537	4.0
	.50	16.2	2,799	20	37	794	3.5
	.4375	14.3	1,553	11	27	666	2.34
	.375	12.3	882	10	19	512	1.7
			20,916	31	59	1,379	15.2
6 x 3½	.8125	24.0	15	1	1	150	0.1
	.75	22.4	267	5	6	229	1.17
	.6875	20.6	533	3	6	82	6.5
	.625	18.9	1,817	9	8	446	4.1
	.5625	17.1	2,237	12	20	362	6.2
	.50	15.3	10,149	29	54	1,197	8.5
	.4375	13.5	14,555	31	58	1,369	10.6
	.375	11.7	22,310	31	58	1,498	14.9
	.3125	9.8	128	5	10	283	0.45
			52,011	34	60	1,508	34.6

UNEQUAL LEG ANGLES (Cont'd)

Size of Shapes	*Section Thick-ness*	*Wt. in pounds per ft.*	*Total Quantity Req'd*	*Used in Designs*	*Used in Yards*	*Used in Hulls*	*Average Quantity per Hull*
5 x 4	.8125	22.7	31	1	3	30	1.03
	.625	17.8	7	2	2	10	0.7
	.5625	16.2	636	6	7	330	1.9
	.50	14.5	54	4	5	76	0.71
	.4375	12.8	12	2	2	45	0.27
	.375	11.0	254	5	10	344	0.74
			994	10	19	488	2.03
5 x 3½	.75	19.8	34	3	4	163	0.21
	.6875	18.3	126	1	1	70	1.8
	.625	16.8	421	5	5	348	1.21
	.5625	15.2	155	4	5	169	0.92
	.50	13.6	1,504	17	31	799	1.9
	4375	12.0	3,638	25	42	925	3.9
	.375	10.4	3,713	21	36	927	4.0
	.3125	8.7	80	5	9	137	0.58
			9,671	30	50	1,173	8.25
5 x 3	.6875	17.1	1,065	2	4	120	8.9
	.625	15.7	15	1	1	150	0.1
	.5625	14.3	4	1	1	2	2.0
	.50	12.8	391	11	20	443	0.88
	.4375	11.3	3,908	20	41	1,017	3.8
	.375	9.8	10,780	28	60	1,434	7.5
	.3125	8.2	2,260	17	30	884	2.56
			18,423	31	60	1,485	12.4
4½ x 3	.375	9.1	176	2	2	24	7.3
	.3125	7.7	81	2	4	24	3.4
			257	3	5	44	5.9
4 x 3½	.625	14.7	111	2	4	87	1.3
	.5625	13.3	166	5	5	112	1.48
	.50	11.9	300	16	25	696	0.43
	.4375	10.6	4,309	16	27	616	7.0
	.375	9.1	551	15	26	657	0.84
	.3125	7.7	1	1	1	70	0.014
			5,438	21	36	916	5.9
4 x 3	.625	13.6	89	4	8	131	0.68
	.5625	12.4	253	4	8	114	2.2
	.50	11.1	537	13	32	537	1.0
	.4375	9.8	14,338	32	54	1,343	10.7
	.375	8.5	39,712	35	54	1,460	27.2
	.3125	7.2	1,539	16	26	637	2.4
	.25	5.8	1	1	1	2	0.5
			56,469	34	60	1,508	37.4

UNEQUAL LEG ANGLES (Cont'd)

Size of Shapes	Section Thick-ness	Wt. in pounds per ft.	Total Quantity Req'd	Used in Designs	Used in Yards	Used in Hulls	Average Quantity per Hull
3½ x 3	.625	12.5	3	1	1	110	0.027
	.5625	11.4	1,591	5	6	242	6.6
	.50	10.2	2,523	8	10	398	6.35
	.4375	9.1	8,043	12	19	571	14.1
	.375	7.9	6,064	24	49	1,019	5.95
	.3125	6.6	2,237	16	29	709	3.16
	.25	5.4	5,558	2	2	220	25.3
			26,019	27	49	1,099	23.7
3½ x 2½	.50	9.4	3	1	1	4	0.75
	.4375	8.3	24	3	3	136	0.18
	.375	7.2	369	7	16	571	0.65
	.3125	6.1	1,351	12	27	595	2.28
	.25	4.9	33	3	12	322	0.1
			2,780	15	30	811	3.4
3 x 2½	.50	8.5	15	2	2	120	0.125
	.4375	7.6	73	3	4	149	0.49
	.375	6.6	657	16	28	770	0.85
	.3125	5.6	3,971	25	49	1,192	3.3
	.25	4.5	271	10	13	416	0.65
			4,987	26	49	1,193	4.2
3 x 2	.4375	6.8	6	1	1	14	0.43
	.375	5.9	3	2	2	181	0.017
	.3125	5.0	18	1	1	24	0.75
	.25	4.1	17	3	3	39	0.44
			44	6	6	235	0.19
2½ x 2	.375	5.3	19	3	4	268	0.07
	.3125	4.5	170	6	16	368	0.46
	.25	3.62	84	10	16	483	0.17
	.1875	2.75	16	2	7	122	0.13
			289	13	24	651	0.44
2½ x 1½	.25	3.19	1	2	2	115	0.01
	.1875	2.12	5	1	1	110	0.045
			6	2	2	115	0.05

BULB ANGLES (restricted)

Size of Shapes	Section Thick-ness	Wt. in pounds per ft.	Total Quantity Req'd	Used in Designs	Yards	Hulls	Average Quantity per Hull
10 x 3½	.675	33.0	533	2	2	21	25.4
	.65	32.1	1,061	2	4	39	27.2
	.625	31.1	1,680	2	3	32	52.5
	.575	29.1	553	3	4	24	23.0
10 x 3½	.55	27.9	119	1	1	4	29.7
	.525	26.9	826	5	7	70	11.8
	.50	25.9	4,084	9	11	107	38.2
	.475	24.9	801	4	5	30	26.7
	.45	23.9	454	4	4	34	13.3
			10,111	12	16	199	51.0
9 x 3½		31.7	3	1	1	4	0.75
	.65	29.5	27	1	2	4	6.75
	.625	28.6	8	1	1	4	2.0
9 x 3½	.55	25.7	8	2	4	6	1.33
	.525	24.8	112	3	5	19	5.9
	.50	23.9	244	5	5	35	7.0
9 x 3½	.475	22.7	579	5	5	38	15.2
	.45	21.8	3,077	6	8	70	44.0
	.425	20.9	458	4	6	31	14.8
	.40	20.0	390	6	5	38	10.3
			4,906	9	13	132	37.2
8 x 3½	.65	26.5	324	1	2	20	16.2
	.525	22.4	79	1	1	10	7.9
	.50	21.7	633	4	7	50	12.7
	.475	20.5	272	2	5	26	10.5
	.45	19.6	2,652	8	11	78	34.0
	.425	18.8	529	7	9	68	7.8
	.40	18.0	4,946	9	12	103	48.0
			9,435	10	15	155	61.0
8 x 3	.425	18.0	14	1	1	4	3.5
	.40	17.2	941	4	7	108	8.7
			955	4	8	112	8.5
7½ x 3½	.50	20.4	29	1	1	4	7.25
7½ x 3½	.425	17.8	10	1	1	4	2.5
	.40	17.0	238	1	1	4	59.5
			277	1	1	4	69.3
7½ x 3	.35	14.8	0.2	1	1	2	0.1
7 x 3½	.575	21.6	88	1	2	13	6.8
	.525	20.1	36	1	1	11	3.3
	.475	18.7	439	2	2	10	43.9
7 x 3½	.475	18.3	118	1	1	21	5.6

BULB ANGLES (cont'd)

Size of Shapes	*Section Thick-ness*	*Wt. in pounds per ft.*	*Total Quantity Req'd*	*Used in* Designs	Yards	Hulls	*Average Quantity per Hull*
7 x 3½	.45	17.6	1,204	9	11	107	11.2
	.425	16.8	1,201	3	4	32	37.8
	.40	16.2	1,824	7	10	123	14.8
	.375	15.5	1,964	6	7	56	35.1
	.35	14.8	400	4	3	28	14.3
			7,274	13	18	268	27.0
7 x 3	.475	17.7	549	1	1	4	137.0
	.45	16.9	1,479	3	3	26	57.0
7 x 3	.425	16.0	6	1	2	4	1.5
	.40	15.3	3	1	2	2	1.5
	.375	14.6	4,000	2	5	160	25.0
	.35	13.9	0.2	1	2	2	0.1
			6,037.2	3	8	195	31.0
6½ x 3½	.425	16.7	27	1	1	10	2.7
	.375	14.3	5	1	1	10	0.5
			32	1	1	10	3.2
6½ x 3	.35	12.9	0.2	1	1	2	0.1
6 x 3½	?	17.8	33	1	1	10	3.3
6 x 3	.50	16.2	51	3	4	29	1.76
	.475	15.6	161	2	2	20	8.05
	.45	14.9	784	6	13	145	5.4
6 x 3	.425	14.1	627	7	7	108	5.8
	.40	13.4	1,943	8	13	132	14.7
	.375	12.8	3,450	9	17	139	24.8
	.35	12.2	4	1	3	10	0.4
			7,020	18	30	464	15.1
5½ x 3	.425	13.4	1	1	1	4	0.25
5½ x 3	.40	12.5	25	1	1	6	4.2
	.375	11.9	6	2	2	6	1.0
			32	2	3	12	2.7
5 x 2½	.328	10.3	12	1	1	8	1.5
	.313	10.0	2	1	1	1	2.0
			14	2	2	9	1.5

SHIP CHANNELS

Size of Shapes	*Section Thick-ness*	*Wt. in pounds per ft.*	*Total Quantity Req'd*	*Used in Designs*	*Yards*	*Hulls*	*Average Quantity per Hull*
12 x 4	.84	50.0	1,452	1	4	46	31.6
	.75	46.3	249	3	3	59	4.2
	.70	44.3	11,198	10	15	415	27.0
	.595	40.0	7,566	11	18	470	16.1
	.473	35.0	10,805	15	29	677	16.0
			31,270	15	31	753	41.5
12 x 3½	.61	37.2	2,552	7	9	196	13.0
	.50	32.7	17,179	15	21	627	27.4
	.44	30.2	9,421	15	25	691	13.6
	.375	29.3	1,764	5	6	54	32.7
			30,916	22	32	838	37.0
10 x 4	.741	40.0	147	1	1	21	7.0
	.65	36.9	2,101	4	6	254	8.3
	.50	31.8	2,227	3	7	124	17.9
	.447	30.0	8,179	4	4	134	61.0
			12,654	10	16	481	26.3
10 x 3½	.675	33.2	78	2	2	39	2.0
	.60	30.6	2,468	5	9	200	12,3
	.55	28.9	20,796	9	19	434	48.0
	.50	27.2	28,195	21	40	781	36.0
	.475	26.4	15	3	7	129	0.12
	.375	23.5	70	1	2	11	6.3
			51,622	21	42	925	56.0
10 x 3⅜	.575	28.5	837	2	4	29	28.8
	.50	26.0	443	7	10	283	1.57
	.45	24.3	9,109	6	10	205	44.5
	.40	22.6	1,054	4	13	231	4.6
	.375	21.7	20,712	17	28	677	30.6
			32,155	19	38	852	37.8
9 x 4	.65	34.7	1,485	4	6	91	16.3
	.55	31.7	375	4	5	90	4.2
	.45	28.6	29,337	11	14	300	97.5
			31,197	11	14	300	104.0
9 x 3½	.50	26.9	71	1	1	1	71.0
	.45	25.4	31	1	1	10	3.1
	?	21.8	2	1	1	2	1.0
			104	3	3	13	8.0

SHIP CHANNELS (cont'd)

Size of Shapes	*Section Thick-ness*	*Wt. in pounds per ft.*	*Total Quantity Req'd*	*Used in Designs*	*Yards*	*Hulls*	*Average Quantity per Hull*
8 x 3½	.625	27.2	301	3	10	151	2.0
	.60	26.5	561	8	10	328	1.7
	.55	25.2	7,082	2	7	107	66.0
	.50	23.8	18,232	22	40	838	21.8
	.425	22.7	14	2	2	28	0.5
	.415	21.5	20,349	17	38	1,008	20.1
			46,539	26	42	1,060	44.0
8 x 3	.40	19.3	2	1	2	11	0.18
	.344	17.6	17	2	6	114	0.15
			29	2	6	114	0.25
7 x 3½	.55	23.3	69	2	4	41	1.7
	.50	22.1	138	7	10	158	0.9
	.45	20.9	11,420	19	35	858	13.3
	.40	20.2	444	2	3	12	37.0
	.40	19.7	23,709	16	31	890	26.6
			35,780	24	45	1,178	30.4
7 x 3⅜	.575	21.9	25	1	1	70	0.36
	.438	18.6	55,403	22	38	957	57.8
	.35	16.5	25,392	21	30	851	29.8
	.313	15.6	4,674	10	18	631	7.4
			85,494	28	48	1,250	68.3
6 x 3⅝	.535	21.5	133	2	3	121	1.1
	.41	19.0	183	9	12	293	0.63
			316	10	14	325	0.98
6 x 3½	.375	17.9	146	1	2	28	5.2
	.35	15.0	40,874	29	48	1,238	29.6
			41,020	29	49	1,248	32.9
6 x 3	.563	18.1	66	3	3	41	1.6
	.313	13.0	4,950	7	10	519	9.5
			5,016	8	12	550	9.1
6 x 2½	.313	12.5	1,373	3	9	202	6.8
4 x 2	.394	10.1	60	1	2	13	4.6

STRUCTURAL CHANNELS

Size of Shapes	*Section Thick-ness*	*Wt. in pounds per ft.*	*Total Quantity Req'd*	*Used in Designs*	*Yards*	*Hulls*	*Average Quantity per Hull*
18 x 4	.63	55	83	1	1	110	0.75
15 x 3½	.818	55	240	2	7	184	1.3
	.72	50	1,053	7	6	242	4.35
	.622	45	76	2	2	152	0.5
	.524	40	2,660	10	15	403	6.6
	.426	35	722	2	4	22	32.8
	.40	33	11,034	8	16	559	19.7
			15,785	14	21	640	24.6
13 x 4	.678	45	538	2	6	114	4.7
	.497	37	916	1	1	8	114.5
	.452	35	1,337	3	2	43	31.1
	.375	32	262	2	2	10	26.2
			3,053	7	12	161	18.9
12 x 3	.758	40	15	1	1	22	0.68
	.636	35	12,301	4	5	296	41.6
	.513	30	8,493	4	6	289	29.4
	.39	25	6,009	6	6	357	16.8
	.28	20.5	2,072	6	8	331	6.3
			28,890	11	13	527	54.8
10 x 2¾	.676	30	255		2	154	1.65
	.529	25	62	1	2	154	0.4
	.382	20	753	4	6	287	2.62
	.24	15	77	4	4	275	0.28
			1,147	6	8	302	3.8
9 x 2½	.615	25.0	711	1	2	154	4.6
	.452	20.0	3,386	2	3	159	21.3
	.23	13.25	3	1	1	5	0.6
			4,100	2	3	159	25.8
8 x 2⅜	.582	21.25	15	1	1	22	0.68
	.49	18.75	1,801	2	3	164	11.0
	.399	16.25	4,137	2	3	176	23.4
	.307	13.75	586	2	3	164	3.57
	.22	11.25	64	1	2	154	0.42
			6,603	3	4	186	35.5
7 x 2¼	.423	14.75	225	2	2	21	10.7
	.318	12.25	933	2	3	276	3.38
	.21	9.75	63	1	1	5	12.6
			1,221	4	5	297	4.1
6 x 2⅛	.563	15.5	307	1	2	154	2.0
	.44	13.0	7	1	1	150	0.047
	.318	10.5	123	3	7	118	1.04
	.20	8.0	27	2	2	181	0.15
			464	3	9	271	1.7
5 x 2	.477	11.5	1	1	1	5	0.2
4 x 1⅝	.325	7.25	1	1	1	4	0.25
	.252	6.25	5	1	1	1	5.0
			6	1	2	5	1.2

I BEAMS

Size of Shapes		Section Thickness	Wt. in pounds per ft.	Total Quantity Req'd	Used in Designs	Used in Yards	Used in Hulls	Average Quantity per Hull
28	x 10	.50	105	236	1	1	8	29.5
26	x 9½	.46	90	582	1	1	8	72.7
24	x 9	.476	74	4,565	2	2	118	38.7
24	x 7	.631	90.	233	1	1	150	1.55
		.50	80	683	1	2	154	4.5
				916	1	2	154	5.9
20	x 7	.60	80	189	1	1	70	2.7
20	x 6¼	.50	65	133	2	2	220	0.6
18	x 11½	.48	92	395	1	2	154	2.6
18	x 7½	.32	52	1,827	1	1	70	26.1
18	x 7½	.38	48	218	2	2	18	12.1
18	x 7	.562	75	165	1	1	150	1.1
18	x 6	.555	60	115	1	1	110	1.05
		.46	55	9	1	1	12	0.75
				124	2	2	122	1.01
15	x 6¾	.44	46	1,036	1	1	70	14.8
15	x 6	.59	60	7	1	1	8	0.88
15	x 5½	.656	55	45	2	5	48	0.94
		.41	42	2,329	4	10	319	7.3
				2,374	6	15	367	6.5
12	x 5¼	.46	40	628	6	8	269	2.3
12	x 5	.436	35	187	3	3	48	3.9
		.35	31.5	13	2	2	21	0.62
				200	5	5	69	2.9
10	x 4¾	.749	40	19	1	1	31	0.61
		.602	35	9	1	1	8	1.13
		.31	25	73	1	5	104	0.7
				101	3	7	143	0.7
9	x 4⅜	.406	25	19	2	5	96	0.2
8	x 4	.541	25.5	37	1	1	122	0.3
		.27	18.0	26	2	4	132	0.2
				63	3	5	254	0.25
7	x 3¾	.25	15	3	1	1	22	0.14
6	x 3⅜	.352	14.75	55	2	4	83	0.66
5	x 3	.21	9.75	1	2	2	18	0.06
4	x 2¾	.337	9.5	8	1	1	31	0.26

H Pillars

Size of Shapes	Section Thick-ness	Wt. in pounds per ft.	Total Quantity Req'd	Designs	Yards	Hulls	Average Quantity per Hull
14	1.17	236	133	1	1	70	1.9
	.82	162	206	2	3	84	2.5
	.67	130.5	781	1	1	110	7.1
	.63	122.5	96	1	1	22	4.35
	.59	114.5	64	2	2	27	2.37
	.55	106.5	49	1	1	5	9.8
	.51	99	67	1	1	70	0.96
	.47	91	208	2	2	27	7.7
	.43	83.5	270	1	1	150	1.8
			1,874	6	5	371	5.1
12	.78	132.5	164	2	4	25	6.55
	.74	125.5	396	2	3	164	2.41
	.70	118.5	63	1	1	70	0.9
	.67	112	387	5	8	259	1.5
	.63	105	150	4	7	189	0.8
	.59	98.5	113	2	4	25	4.5
	.55	91.5	188	3	5	175	1.07
	.51	84.5	465	3	5	244	1.9
	.43	71.5	246	2	3	224	1.1
	.39	64.5	21	1	1	70	0.3
			2,193	7	10	389	5.6
10	.63	88.5	11	1	1	10	1.1
	.59	82.5	15	2	3	24	0.6
	.55	77	42	3	4	46	0.9
	.47	65.5	112	3	5	39	2.9
	.43	59.5	151	4	6	54	2.8
	.39	54	168	3	6	181	0.93
	.36	49	19	1	1	22	0.86
			518	8	12	248	2.1
8	.63	71.5	483	2	3	121	4.0
	.55	62	7	2	4	25	0.28
	.51	57.5	14	1	2	11	1.27
	.47	53	13	1	2	14	0.93
	.43	48	52	2	3	16	3.3
	.39	43.5	59	4	6	40	1.5
	.35	39	135	4	6	63	2.14
	.31	34.5	33	3	4	29	1.14
	.31	32	55	2	4	31	1.8
			851	8	11	205	4.1
6	.313	23.8	20	2	4	26	0.77
5	.313	18.7	10	2	3	24	0.42
4	.313	13.6	26	2	3	18	1.44

TEES

Size of Shapes	Section Thickness	Wt. in pounds per ft.	Total Quantity Req'd	Designs	Used in Yards	Hulls	Average Quantity per Hull
6½ x 6½	.45	19.8	5,760	14	19	409	14.1
6 x 5¼	1.375	39.4	51	1	1	32	1.59
6 x 4½	1.06	28.2	77	2	2	42	1.83
6 x 4	.5625	15.6	101	4	4	26	3.9
5 x 3	?	13.6	81	4	4	48	1.7
4½ x 3	.4375	9.8	65	2	3	85	0.77
4 x 5	?	11.9	27	1	1	32	0.84
4 x 4	.5625	13.5	16	1	1	8	2.0
4 x 4	.4375	10.5	126	3	8	122	1.03
4 x 3	.4375	9.2	7	1	1	46	0.15
4 x 3	.375	7.8	5	1	1	46	0.11
3½ x 3½	.4375	9.2	13	1	1	22	0.59
3 x 3	.375	6.7	1	1	1	8	0.13

ZEES

Size of Shapes	Section Thickness	Wt. in pounds per ft.	Total Quantity Req'd	Designs	Used in Yards	Hulls	Average Quantity per Hull
6	.375	15.7	12	1	1	10	1.2
	?	14.6	71	1	1	12	5.9
			83	1	1	12	6.9
5	.3125	11.6	22	1	1	32	0.69
4	.375	12.5	1	1	2	13	0.08
3	.50	12.6	13	1	1	5	2.6
3	.4375	11.5	129	1	1	30	4.3
	.375	9.8	440	3	8	169	2.6
			569	3	8	199	2.8
3	.3125	8.5	13	2	3	19	0.7
2½	.50	13.6	753	5	7	141	5.3

APPENDIX E

showing variety of rolled steel shapes and section thicknesses (tabulated by designs and shipyards) specified for the 1508 vessels covered by report of Oct. 15, 1918, to Emergency Fleet Corporation.

Approx. D.W.T.	*E.F.C. Design*	*Shipyard*	*Number of Ships*	*Variety of Section Shapes*	*Variety of Section Thicknesses*	
		CARGO SHIPS				
12,500	Req.	Pennsylvania S.B.	11	21	53	
11,925	Req.	New York S.B.	2	33	77	
11,800	56	Bethl.—Alameda	18	36	80	
10,000	18	Sun S.B.	12	24	51	
9,600	37	Federal S.B.	30	25	67	Approx.
		Carolina S.B.	12	29	71	
		Doullut & Williams	8	31	85	
9,500	27	Oscar Daniels	10	33	72	Approx.
	Req.	Cramp S.&E.B.	2	31	86	
9,400	15	Groton	6	22	52	
		Virginia	12	22	52	Approx.
		Moore S.B.	25	21	49	
		Pacific Coast S.B.	10	25	56	
		Union Constr'n	10	24	50	
		Seattle N. Pacific	10	23	53	
		Standifer	10	16	44	
	79	Skinner & Eddy	46	26	72	
9,000	25	Newburgh	10	35	98	Approx.
		Merrill-Stevens	6	35	98	Approx.
		Pensacola	10	29	86	
		Chester	18	35	98	
		Merchant	60	35	98	
8,800	19	Atlantic	10	26	60	
		Long Beach	8	20	52	
		Southwestern	10	27	65	
		Western Pipe	18	24	64	
	16	Groton	6	34	87	Approx.
		Baltimore D.D.	8	34	87	
	13	Los Angeles	30	22	45	
		Columbia River	32	34	73	
		Northwest Steel	31	33	63	
		Skinner & Eddy	31	26	66	
	66	Duthie	22	36	88	
	80	Ames	25	27	57	
7,500	17	Downey	10	27	54	
	14	Seattle Constr'n	21	17	36	
	22	Hog Island	110	36	118	
	Req.	Pennsylvania S.B.	2	32	60	

Approx. D.W.T.	*E.F.C. Design*	*Shipyard*	*Number of Ships*	*Variety of Section Shapes*	*Variety of Section Thicknesses*	
		CARGO SHIPS (cont'd)				
7,400	63	Standard	23	25	56	
		Beth.—Sp.P.&H.&H.	9	28	84	
5,350	43	Hanlon	8	26	54	
5,000	23	Bayles	4	39	106	
		Submarine	150	42	118	
	Req.	New Jersey S.B.	12	23	46	
4,350	Req.	Pusey & Jones	10	23	48	
4,200	60	American S.B.	60	20	46	
		Great Lakes	24	24	42	
4,050	60	American S.B.	60	20	46	Approx.
	74	Globe	5	16	29	
		Great Lakes	24	18	29	
		Manitowoc	12	17	31	
		McDougall-Duluth	15	16	29	Approx.
		Saginaw	12	16	29	Approx.
		Toledo	16	19	45	
3,800	49	Albina	13	19	37	
3,500	20	American S.B.	56	19	43	Approx.
		Globe	10	19	43	
		McDougall-Duluth	10	19	43	Approx.
		Saginaw	12	21	37	
		Toledo	8	20	43	
	Req.	Staten Island	5	21	43	
3,400	44	Manitowoc	14	21	38	
		CARGO—TRANSPORTS				
10,000	29	New York S.B.	3	24	56	
8,000	24	Hog Island	70	32	129	
5,000	Req.	Cramp S.&E.B.	3	25	55	
		COLLIER				
8,600	Req.	New York S.B.	5	30	60	
		TANKERS				
?	Navy	Newport News	8	28	59	
12,650	Req.	New York Ship	4	34	91	
10,300	59	Baltimore D.D.	12	22	61	
10,150	Req.	Sun S.B.	8	30	56	
10,000	47	Bethl.—Sp.P.&Un.	28	29	62	
	41	Moore S.B.	6	19	38	
9,800	Req.	Texas S.S.	4	36	88	

Approx. D.W.T.	E.F.C. Design	Shipyard	Number of Ships	Variety of Section Shapes	Variety of Section Thicknesses	
		TANKERS (cont'd)				
7,500	31	Bethl.—H.&H.	3	39	83	
		Terry S.B.	10	39	83	Approx.
6,000	58	Baltimore D.D.	6	19	33	
4,800	Req.	Bethlehem—Moore	1	23	41	
		TUGS				
Ocean	35	Bayles	2	10	13	
		Bethlehem—Moore	20	12	14	
		Newburgh	3	12	16	
		Providence	10	11	12	
		Whitney	10	9	11	
Harbor	36	Johnson	6	8	12	
		Northwest Eng.	2	8	12	Approx.

STANDARDIZATION OF SHIP MATERIALS

SYNOPSIS

1. Scope of paper—mainly steel cargo ships.
2. Purpose and phases of standardization.
3. Miscellaneous ship parts and materials.
4. Preponderance of hull steel.
5. Comparison of ship with bridge design.
   a. Control during operation.
   b. Stress computations.
6. Classification Society Rules.
7. Opportunities for standardizing.
8. Difficulties in standardizing:—
   a. Importance of saving weight.
   b. Watertight essentials.
   c. Sections peculiar to ships.
   d. Sections undesirable in ships.
   e. Ambiguity of terms used.
9. Materials used the criterion.
10. Relation of plain material to total cost.
11. Need for standardizing:—
    a. Plates.
    b. Practice in ordering.
    c. Shapes.
    d. Bars.
12. Ill effects of non-standardization and the remedy.
13. Standardization in British Isles.

SYNOPSIS (*continued*)

14. Standardization in United States:—
    a. Recommendations of July, 1917.
    b. Their benefit only partial.
    c. How to make more effective.
    d. Report of October, 1918.
    e. Conference and recommendations of November, 1918.
    f. Adoption of certain New American Standard Sections:—
        —No previous United States Standards.
        —Engineering Standards Committee.
        —British compared with United States rolling mill practice.
        —Combination of advantages of both.
    g. Incidental application to car-builders.
15. Results of standardization:—
    a. Plates.
    b. Shapes.
16. Lasting benefit anticipated.

APPENDICES

A. Tentative classification of steel ship parts, according to function.

B. Tentative classification of steel ship materials, according to products.

C. Topics suggested for consideration in standardization of miscellaneous materials.

D. Detailed tabulation of quantities of rolled steel shapes and sections specified, prior to standardization, for the hulls covered by Appendix E, with totals per Design, Shipyard, and Hull; and averages.

E. Detailed tabulation of variety of rolled steel shapes and sections specified, prior to standardization, by 60 shipyards in 44 designs for 1508 ships analysed.

VICE-PRESIDENT TOPPING: The next paper, gentlemen, is by Mr. J. A. Mohr, on Method of Charging Raw Materials into the Blast Furnace.

MR. J. A. MOHR: Mr. Chairman and gentlemen: I have a few pictures with the paper, which with your permission I will defer until after the reading of the paper.

METHOD OF CHARGING RAW MATERIALS INTO THE BLAST FURNACE

JACOB A. MOHR

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During the early history of blast furnace operation the method of charging materials was a logical sequence of the other operating conditions. The furnaces were about thirty feet high, and lack of transportation facilities caused them to be located at the ore mines, preferably close to a hill, from which, due to their low height, a platform ran to the furnace top. At first, the quantities of ore, fuel and flux were not measured in any standard way, but were hauled in wagons to the furnace top, and shoveled in according to the individual ideas of the particular operator. Later, scales and hand barrows were installed, and the materials, after being dumped from the wagons, were shoveled into barrows and weighed before dumping into the furnace. The development from this period to the present day methods of handling and charging materials has been so comparatively recent that all present day operators are familiar with it. So long as raw materials maintained their early qualities of purity and excellence, the question of methods was not of such great importance. Later, however, next to the quality of the raw materials themselves, no more important developments in blast furnace design and operation were found than those dealing with the proper methods of charging raw materials.

The raw materials charged into the blast furnace are four, namely:

(1) Iron Bearing Materials.	Ore. Cinder. Scale. Briquettes, etc.	Downcomer Dust. Scrap. Sinter.
(2) Fuel.	Coke. Anthracite. Charcoal.	

(3) Flux. {Limestone. Dolomite.

(4) Air.

The approximate quantities used per ton of iron produced are 4,300 pounds ore, 2,000 pounds coke, 1,000 pounds limestone, and 7,800 pounds air, when smelting Mesaba ores.

Method of Charging Air

No other raw material has so little variance in the method of charging. Air supplied may vary in uniformity, due to temperature, moisture, and atmospheric pressure. Many blast furnace managers have found it to be of advantage to adjust the quantity of air supplied according to the existing conditions of temperature and pressure. This is done by adjusting the revolutions with the existing atmospheric conditions of temperature and barometric pressure, so that the actual pounds of air delivered to the furnace will remain constant. Efforts have also been made to eliminate the irregular flow of air as received from reciprocating blowers, by the use of turbo blowers. No general sentiment favors the turbo blower at present; however, the uniform supply of air which they seek to attain is of importance, and their practicability as a blower should receive the attention of every operator.

The moisture in the air varies during the year as high as ten grains per cubic foot, several different methods having been devised to eliminate this variation. These methods may be divided into three general classes—the dry cold, chemical, and those resorting to the use of cooling liquid in direct contact with the air.

The dry cold method consists of cooling the air to a sufficiently low temperature to condense the contained moisture. This method reduces the moisture to about two grains or less per cubic foot of air. The Gayley Dry Blast is the best known method of this type.

The chemical methods are nearly all based on the

affinity of dry calcium chloride for moisture, and vary mainly in the methods of effecting the contact between the air and salt, the cooling of the salt, and its regeneration. Considerable heat is required in this method to regenerate the saturated calcium chloride.

The third method, that of using a cooling liquid, is a later development, and probably requires less cost of installation and operation than either of the others. In this method the air is washed by a cold brine consisting of a calcium chloride solution reducing the moisture to the point of saturation for the given temperature.

There is still another method of eliminating the variable amount of moisture in the air by adding steam to the air in the cold blast main in such quantities as to produce a moisture content in all cases close to the maximum amount that may be expected under weather conditions existing at the particular location. While this method does effect a uniformity in the condition of the air, it is hardly likely that much good is accomplished by introducing a uniform condition which is undoubtedly uniformly bad.

While the elimination of the moisture content of the air is of great benefit to the furnace, the methods so far devised are so costly in installation and operation that but few plants have adopted them, and it can be said that at present they are hardly to be found of any economic value, except under certain special conditions.

The composition of the air has received a great deal of attention, from a theoretical standpoint only, in consideration of the inert nitrogen content. Elimination of nitrogen, partially or otherwise, would decrease greatly the amount of work done by the blowing engines; it would also lessen the amount of heat required from the stoves; would intensify reactions in the furnace hearth; reduce the amount of flue dust produced by reducing the volume, and, therefore, the velocity, of the gases passing out of the furnace; increase the flame temperature of the gas, and decrease the amount of heat carried away by the

stack gases of the stoves and boilers. However, while the nitrogen has been separated from the oxygen of the air in comparatively small quantities, the utilization of any present methods for the large volume of air required in furnace work is commercially impossible, and much remains for the scientist to accomplish before any of its benefits can be acquired by the operator.

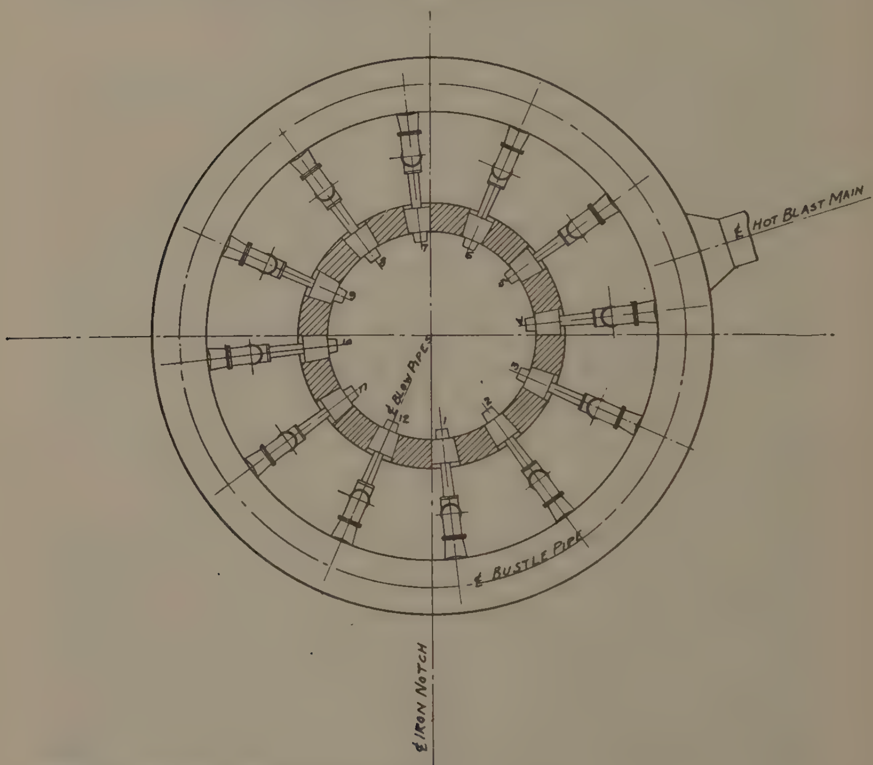


Fig. 1. Showing arrangement of tuyeres, bustle pipe and hot blast connections.

The hot blast main and bustle pipe should be so designed and arranged as to insure a good distribution of air to the several tuyeres. A necessity to accomplish this is the use of clean gas, as dirty gas accumulates dust in the stove, which is carried over and deposited in the bustle pipe, obstructing the uniform flow of the air. In consideration of this possibility of unequal distribution of

air to the tuyeres, a test was made at Carrie Furnaces on No. 4 Furnace to find if there was any appreciable difference in the amount of air passing through the tuyeres. At the time of the test this furnace had been in about three years, and as we use dirty gas in the stoves the bustle pipe would have considerable dust deposited in it during this period. All the blow pipes, twelve in number, were replaced with pipes drilled, tapped and fitted up with pitot tubes. Ellison's differential gages were used, with water as an indicating fluid.

The blow pipes and tuyeres were all of the same size, and were well cleaned. Rubber tubes were used to connect the pitot tube ends to the differential gages, and we experienced considerable trouble with these burning off and having to be replaced, this condition causing us to lose the readings that are missing in the table. Readings were also taken throughout the test of the static pressures at each blow pipe. The results of the test are tabulated below. An arrangement of tuyeres, bustle pipe and hot blast connection is shown in Fig. 1.

From a study of the results obtained it is seen that the amount of air passing through the tuyeres is fairly constant for each individual tuyere, but the different tuyeres vary considerably. Also, this variation has no uniformity whatever, but seems to be independent of any condition existing in the bustle pipe, or of the location of the hot blast main connection, which is between No. 4 and No. 5 tuyeres, as shown in Figure 1. The static pressure of the different tuyeres is comparatively uniform, and, therefore, if the resistance inside the furnace was equal at all tuyeres, it is evident that, with the uniform static pressure obtaining, all tuyeres would receive approximately the same amount of air. Therefore, it is logical to assume that the reason for the great variation existing in the amount of air passing through each tuyere is that the resistance in the furnace is not at all uniform, but varies considerably for the

DIFFERENTIAL PRESSURE AT TUYERES, IN INCHES OF WATER

Time.	1	2	3	4	5	6	7	8	9	10	11	12
2:00	....	20.8	18.5	....	16.0	....	11.5	18.5	15.0	21.0	17.0	....
2:10	....	21.0	17.5	....	17.0	....	9.0	18.0	14.5	20.0	15.5	....
2:20	10.5	20.5	17.0	....	17.5	....	8.5	16.5	14.0	18.5	19.0	....
2:30	11.0	21.0	17.0	....	17.0	....	8.0	17.5	14.0	20.0	16.0	....
2:35	10.0	20.5	16.5	....	17.0	....	7.0	17.0	15.5	21.0	....	....
2:45	10.7	19.0	17.0	....	16.5	....	7.5	17.0	15.0	20.5	....	....
3:00	9.5	19.0	16.9	....	16.0	....	7.0	16.6	14.0	16.6	....	....
3:05	10.0	19.3	16.7	....	16.4	....	7.9	17.0	15.0	19.9	14.3	....
3:10	9.6	19.5	17.3	....	16.1	13.5	8.2	17.2	14.3	19.2	10.3	....
3:15	8.2	18.8	16.3	....	16.5	13.2	8.5	16.6	15.0	20.2	12.2	....
3:20	....	21.5	19.0	15.0	17.0	16.0	9.0	17.5	15.0	22.0	12.5	....
3:30	....	....	....	....	....	....	9.0	18.0	16.0	21.0	11.5	....
3:35	....	19.8	17.5	10.3	16.2	13.0	9.0	17.5	16.0	21.5	15.0	....
3:40	10.5	19.9	18.0	9.7	16.7	13.5	....	....	....	....	....	....
3:45	8.9	19.6	16.9	8.0	16.2	13.1	8.9	18.0	15.5	22.0	14.5	....
3:50	....	....	....	....	....	....	9.5	17.0	15.0	20.0	13.5	....
3:55	9.3	18.8	17.1	7.7	16.7	12.1	10.0	17.2	14.9	20.1	14.2	....
4:00	11.8	19.1	17.2	7.4	16.2	12.5	9.5	17.2	15.0	19.9	15.2	....
4:05	....	....	....	....	....	....	9.5	17.3	15.4	17.1	15.3	....
4:10	....	....	....	....	....	....	9.2	16.9	14.0	17.1	11.5	....
4:15	....	....	....	....	....	....	10.1	17.9	15.6	18.8	15.9	....
4:20	....	....	....	....	....	....	9.2	17.3	15.2	18.3	....	....
Average	10.0	19.9	17.2	9.7	16.6	13.3	8.9	17.3	14.9	19.7	14.3	....
Calculated cu. ft. air per minute passing through each tuyere:												
	2730	3860	3570	2700	3520	3140	2570	3570	3340	3830	3260	
Average Static Pressure in lbs. per square inch:												
	11.88	12.08	12.18	12.52	11.73	12.13	12.47	12.23	12.47	12.27	.....	

different tuyeres. These conclusions lead us to believe that any irregularity existing in the distribution of the air passing into the furnace is a result of the furnace conditions only, and cannot be improved by changes in design or arrangement of the bustle pipe or hot blast main. It seems probable, therefore, that the proper method of distributing the air evenly is to so arrange the raw materials in the top of the furnace as to produce an equal resistance in front of all tuyeres upon their arrival in the hearth. To my knowledge, very little research has been done along these lines, but I hope these conditions will be investigated by the different operators, and some more definite conclusions arrived at which will be of value in eliminating a condition of irregularity that is not equaled in any of the other phases of charging.

Charging of Iron Bearing Materials, Flux and Fuel

The charging of these raw materials presents a rather complex problem, the importance of which cannot be overestimated, and is more complex and more important, the less uniform, the less regular, and the less desirable from any point of view, within physical or chemical composition, these materials are, as such irregularities can, to some extent, be compensated for or counterbalanced through attention to the various details of the method of charging, both in engineering and in operating. This is so important that attention must be given the materials almost from the time they enter the blast furnace plant for proper grading and assorting.

The methods in use by the United States Steel Corporation at the ore mines and docks in grading and mixing the ore are of great value to the furnace operator, and minimize to a great extent the troubles of the operator in this respect. At the mines each car is analyzed before sending to the docks. At the docks the car loads are then distributed to the various bins, according to their analysis. Then the different car loads in the bins are thoroughly mixed in the process of handling into the

boats, then to the receiving docks at the lower lakes, and lastly to the cars for their transportation to the furnaces. This method produces grades of ore which are remarkable in the uniformity of their analysis, and for this reason invaluable to the furnace operator, producing a regularity of raw material which he could not hope to attain without such thorough dissemination of grades as they are shipped from the mines.

The Unloading of Ore and Flux

The average furnace plant uses several different kinds of ores in its furnaces, and the method of stocking these in the yard should be an object of careful study to the operator. Different ores must be kept separate, and at the same time the full capacity of the stock yard must be utilized so that it is necessary to observe closely the arrangement of the two different ores at their junction. This can be done by keeping the level of both piles as nearly the same as practicable, so that the coarse pieces of ore cannot run down the pile and across to the other ore. Also, in order to prevent segregation of the lumps, the ore should be stocked in small piles uniformly over the stock pile, and the next cargo should be filled in between these piles; this operation also giving a good mixing to the various cargoes of the same ore and lessens chances of receiving ore of any great variation in filling the bins, either chemically or structurally.

The ores in the yard should be so arranged that those of very different chemical composition are not adjacent, but are separated by an ore whose analysis is approximately between the two, so that when the ore at the juncture of any two piles is reclaimed it will not vary much in composition from the ore on either side.

For economy of handling, the stock pile should have ample capacity to eliminate handling ore from cars during the winter season. There is also another reason why this is desirable, because the frozen cars of ore are thawed either by means of steam pipes thrust in them

or by burning fires under them. In either case the moisture content of the ores in the cars is changed considerably from the initial amount, and this will cause considerable variation in the actual weight of ore charged as compared with that already in the stock pile, consequently, when part of charge is taken from thawed ore and part from stocked ores, the variation in weight of the metallic contents, caused by the different moisture contents, will produce irregular working of the furnace. Where limestone is stocked, similar precautions should be taken to prevent segregation of lumps.

Bins for Ore, Flux and Fuel

There are many types of bins in use at the present time, the most common being the Brown, Hoover & Mason, Wellman-Seaver-Morgan, and the Baker. Most bins are equipped with mechanically operated doors, both steam and electrical operation. Some modern bins, however, still use hand operated doors. These bins have all been designed to eliminate as much as possible the sticking and arching of the ores in them. However, it is a difficult proposition to do this, and there is no ore bin, to my knowledge, which does not have to be dug out when it is necessary to utilize its full capacity, and in most plants constant attention must be given to the bin to insure that each door will be covered with ore, especially when weather conditions are bad. The bins should be of ample capacity to supply the furnace for a considerable period in case of a breakdown on the ore bridge, and for reasons of economy the capacity should be sufficient to hold a 24-hour supply so it will be unnecessary to work the ore bridges at night. They should be located in relation to the furnaces so that the larries will have the least possible length of travel.

The bin doors have a very special work to perform, and many cases of poor furnace practice are probably caused by the inability of this part of the ore handling machinery to perform its work in the proper manner.

The human element comes in very strongly at this point, and for this reason every possible precaution should be taken by the operator, first, to see that the doors will do their work as well as is possible, and second, that the men perform their duty of weighing accurately. Much depends upon the design of the bin door to make it possible for the men to fill the larries quickly and accurately, and too much time cannot be taken by the operator to attain this object. However, with the best of designs, the ore may occasionally come out of the door with a rush, and fill the larry considerably over the amount necessary. This condition must be met with such a layout of bins and larry cars that it is comparatively easy for the larry car operator to remove the excess amount. In regard to this point, I have seen, on some of the older installations, doors at the bottom of the larry cars from which it is necessary to remove any excess material, because the arrangement at the bin door made it practically impossible for the larryman to remove the material from the top of the larry. It is readily seen what would result if the lower part of the larry was filled with limestone, and the upper portion with ore, say 200 pounds in excess of the required weight—the larryman removes 200 pounds of limestone and goes ahead!

Limestone is generally stored in the same type bins as the ore, and causes little trouble in handling, because of its free running qualities.

Coke bins are generally separate from the ore bins, as there are different requirements necessary for their operation. Coke will travel freely over a much flatter slope than that necessary for the ore, so that the bins can be made comparatively flat and shallow. In order to mix the different cars of coke thoroughly, and thus eliminate the possibility of receiving different qualities of coke in different levels of the furnace, the bin should have a capacity equal to several cars of coke, and coke in any part of the bin should travel freely, to guard against having dead places in the bin where coke will accumulate for

a considerable period of time, and only be used when the bin contents are low. Such places generally accumulate considerable dust, and when this coke is put into the furnace it is liable to cause considerable trouble in the furnace operation.

The importance of screening the coke thoroughly cannot be overestimated, and the bin should be so arranged as to allow for extensive and well designed screens. Besides the bad influence of coke dust on furnace operation, due to its small size, it is much higher in ash and lower in fixed carbon than the average size coke. Comparative analyses taken of the coke dust and coke at Carrie Furnaces show a percentage of 21.5 ash and 74.26 fixed carbon in the coke dust as against 11.83% ash and 83.26% fixed carbon in the average coke.

Much careful experimenting is required to find out just where to stop with the screening of the coke so as not to waste pieces of coke that are all right, and at the same time to remove the dust that would be injurious to the furnace. The slope of the screens, the depth of the stream of coke, the size and arrangement of the holes in the use of plate screens, and the size and distance between bar screens must be determined in each particular case.

We made an experiment some time ago to determine, if possible, the injurious effect of small pieces of coke on the furnace operation. We screened the coke over plate screens with 1¼-inch diameter holes, and then rescreened, by hand, the resulting breeze over ¾-inch screens to remove the smaller particles. The breeze recovered was then charged into the furnace by partly filling the skip with the breeze and then adding the regular run of coke out of the bin. We started with a mixture of 16% breeze and 84% regular coke, and increased the breeze to 25% of the charge. We continued with this amount on the furnace for four days, stopping at the end of that time because of the inability to keep up the supply of hand screened coke. The furnace showed good effects, became hot, and later carried an increased burden

of about 7% without any appearance of becoming cold. This experiment, while not extending over a very long period, satisfied me that much coke that is screened out could be used in the furnace without causing any harm, thus effecting considerable economy.

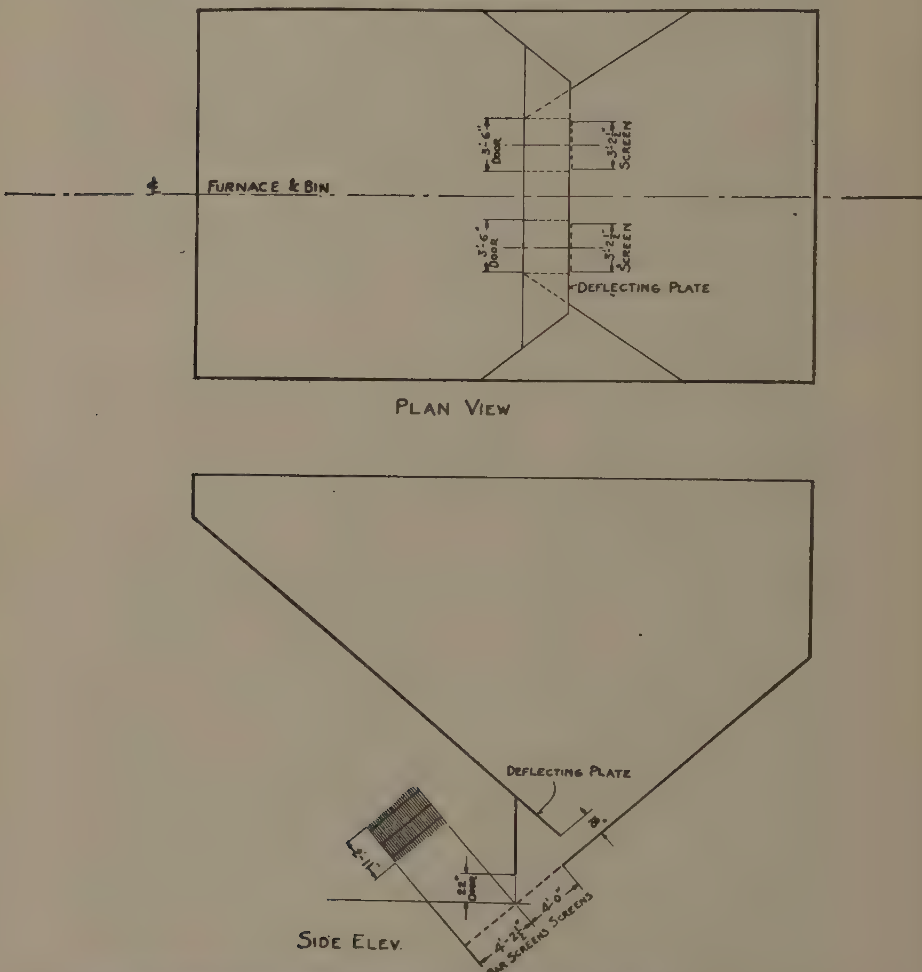


Fig. 2. Arrangement of coke bin an d bar screens at Furnaces 6 and 7

Insofar as my experience has been with coke screens, I prefer the cross bar type of screen, with bars from ⅝-inch to ⅞-inch diameter, and spaced so as to allow an opening of about ¾-inch to 1½-inch between the bars;

these conditions depending upon the size and quality of the individual coke to be screened. The screen should have an angle of about 35 to 45 degrees, and should be located outside of the bin door so as to be readily accessible for cleaning. This type of screen is very easily cleaned by running a coke fork along the bars, and this feature is an additional advantage of no mean importance over other types of screens. We have had these screens installed at Furnaces Nos. 6 and 7 for several years, and they have screened the coke satisfactorily. The amount of dust screened per ton of coke used for the year 1918 was 89 lbs. An illustration of these screens and their arrangement is shown in Figure 2. At Furnaces Nos. 1-2-3-4-5, due to the design of the bins and chutes, we were unable to install the cross bar screens, but have put in plate screens inside the bin the size and arrangement of holes being shown in Figure 3. It was found necessary to have considerably more area if plate screens were used than in the case of bar screens to produce an equal amount of screening. We also found at first that the coke was passing vertically down through the bin to the door, and screening out very little dust. This condition was remedied by placing a deflector plate in the bins, as shown in the illustration, which forced the coke to pass over the screen. This plate extends, as shown, to within 16 to 18 inches of the bin bottom, and causes the coke to pass over the screen in a wide layer, having a depth of a few inches. A poke hole was cut in the front of the bin, and, in case of the coke stopping up, it is a simple matter to poke it out. These plate screens in 1918 removed 93 lbs. of coke dust per ton of coke used. Plate screens are very hard to keep clean, especially when placed inside the bin. These holes also clog up more readily than do bar screens, and for this reason must receive considerably more attention in their operation.

The disposal of the coke dust produced (amounting to about 120 tons per day) has been a difficult problem with us, the only use at present time being for covering

the iron in the ladles, and as a bottom in the soaking pits at Homestead Steel Works, also under boilers, mixed with coal, this amounting to 60% of the total. However, stokers and grates have been developed which will success-

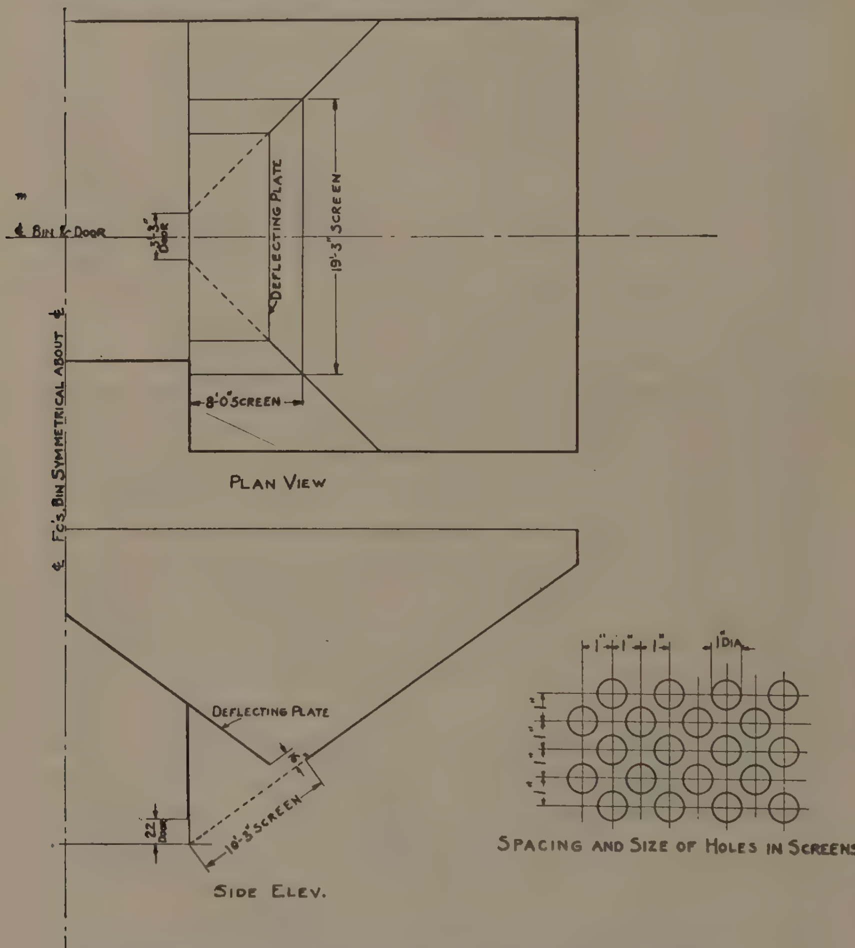


Fig. 3. Arrangement of coke bin and plate screens at Furnaces 3 and 4.

fully burn the coke dust, and eventually all the dust produced will be burned under boilers, replacing a large amount of coal, and resulting in considerable economy; in fact I consider it a fallacy and a waste to burn raw coal under boilers in this advanced day of conservation.

We use the volume method of measuring coke at Carrie Furnaces, the arrangement of our coke bins being such that weighing coke in the larry car is impossible. When measuring different kinds of coke by the volume method, the weight of coke per skip will vary considerably, unless, as stated before, the bin is of such design as to mix the contents of the several cars in it, which will average the different cokes and probably produce as accurate results as the weighing method, which introduces the error of weighing moisture, a variable ranging from 1% to 10%. The volume method has additional advantages in that it gives a constant volume of coke to the round, which helps to stabilize distribution conditions, and in case small dirty coke is encountered, tends to counteract the result by an increase in weight for the same volume. Also, considerable extra labor is required to handle the coke through the larry cars, and additional expense is sometimes incurred in charging the materials by the necessity of using a separate larry car for the coke when weighed.

Under the present conditions, the operator in the Pittsburgh district has to contend with coke from fourteen to twenty different mines and ovens, some of the coke hand drawn and some machine drawn. These conditions produce considerable variation in the weight of coke per unit volume, and militate against the measuring by volume method. However, upon the advent of by-product coke from a single plant at all our furnaces, the present disadvantages of the volume method will lessen considerably, as then we will be using a very much more uniform coke as regards the weight per unit volume, and under these conditions the volume method will appear to be better than the weighing method, which will still have the handicap of variable moisture content to contend with.

Larry Cars

One of the most important phases of the charging of raw materials is to properly weigh the several kinds of

ore bearing materials and the flux in the larry cars before dumping into the skips, and also to so arrange the several materials that there will be a uniformity in their mixture which will be retained through the successive steps subsequent to their delivery in the furnaces, especially in regard to the prevention of the segregation of lumps.

As stated before, the arrangement of larry car and bin should be such as to enable the larryman to readily remove any excess amount of material. This is a most important feature, because it is impossible with any present type of bin door to weigh the material accurately and quickly at all times, and if the work of remedying any over-charge is hard to perform, it is certain that it will not be done, except under conditions of constant supervision, which is a practical impossibility. With the large amounts of material required by the modern blast furnace, the operation of weighing the materials must proceed rapidly, and the larry car must be designed to move at high rates of speed so little time may be lost in transporting the charges. At the skip pit the operation of the doors must be simple, reliable and fast, as a further aid in saving valuable time. There are several types of larry cars on the market with mechanically operated doors, and the advantage they have over hand operated doors is obvious.

Larry car scales present a large problem in themselves; the conditions of operation with which they have to contend is severe, and much attention must be given by the operator to this particular mechanism. Recording scales have been installed on larry cars at many plants, and their adoption has undoubtedly been of great benefit to the operator. These scales are equipped with indicators, which are very convenient in showing the larryman how close he is to the required weight of material he is weighing, this being very much better than the method of judging the amount in the car by feeling the balance on the ordinary scale.

The arrangement of the materials in the larry car, to secure a good mixture, is an essential feature of good charging methods. However, the proper method is dependent upon the individual designs of larry cars and bin doors, and no arrangement can be given that would be suitable for all conditions, but each operator must determine the best method for his individual case.

At all but one of our furnaces we have four larry buckets per furnace, and each bucket fills the same skip in the charge every round, the charge consisting of two ore, two coke, two ore and two coke. A characteristic charge is shown here as illustrating our method of filling the larry car buckets.

		Skip "A"	*Skip "B"*
	(Group No. 3,	5,500	5,500
	(D. C. Briquettes,	1,000	1,000
No. 1 Buckets	(Beaver,	1,500	1,500
	Total,	8,000	8,000
	(Group No. 4,	2,500	2,500
No. 2 Buckets	(Group No. 7,	2,500	2,500
	(Limestone,	3,000	3,000
	Total,	8,000	8,000

The total burden in this case is 26,000 pounds, with 6,000 pounds limestone, and an 11,200 pound coke unit.

It is seen that the two skips will carry the same material in each phase of the ore charge, so that if there is any inequality in the mixture of the materials produced by skip "A," it will be rectified by the following skip "B." Also the amount of material in all buckets is equal, or as nearly so as practicable—this feature helping to establish uniformity in the distribution conditions at the top of the furnace.

As an additional precaution against the segregation of lumps, especially those of large size, we have placed guards against the skip chutes, which hold the lumps until they have been broken up. This also prevents such lumps reaching the receiving hopper on the furnace top where they might possibly stick to the small bell, and thus

interrupt the process of charging, or in any case might disarrange the distribution of the material by stopping the regular flow from the small bell in that particular sector in which they happen to be located. Also as a matter of safety, since we have introduced the guards the men do not have to go on top of furnace to remove lumps

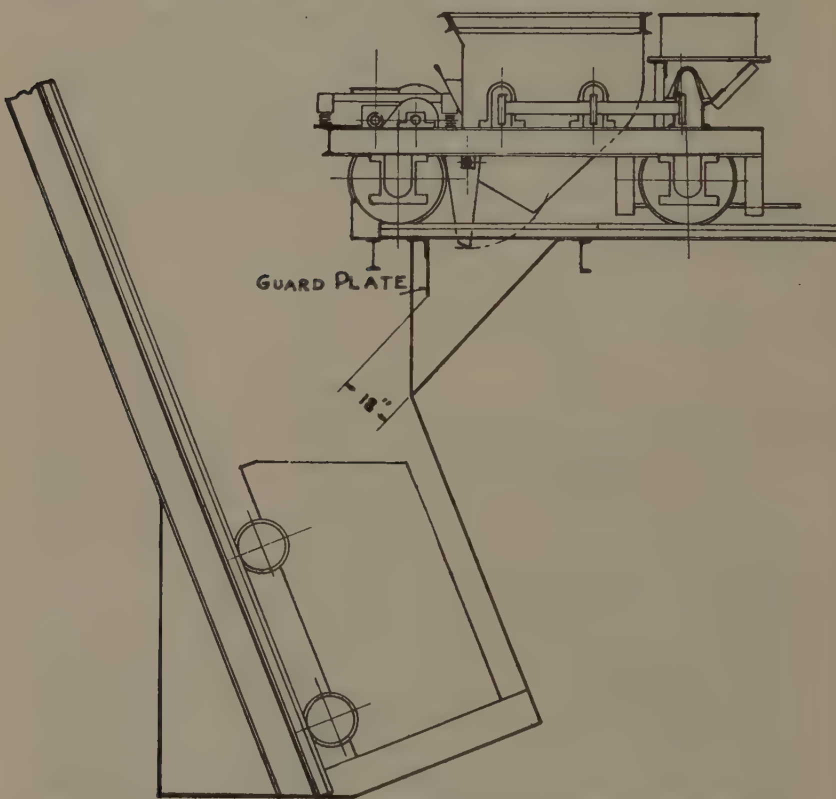


Fig. 4. Arrangement of larry, dumping chute and skip at No. 5 Furnace, showing location of guard plate.

from the small bell, a more or less dangerous proposition on account of the possibility of encountering gas or being caught in a slip.

It would be well at this time to state that the foregoing statements regarding larry cars do not apply in all cases to the Neeland type of charging. In this method, the larry car bucket is of a cylindrical shape and fulfills

the duties in turn of larry car, skip, hopper neck and small bell. With it, the mixing of the materials, the prevention of any segregation, and uniformity of their subsequent distribution on the main bell, depend entirely upon the method of filling the bucket. At first, this system had no method of insuring equal distribution of the materials, excepting that the bucket was filled alternately from

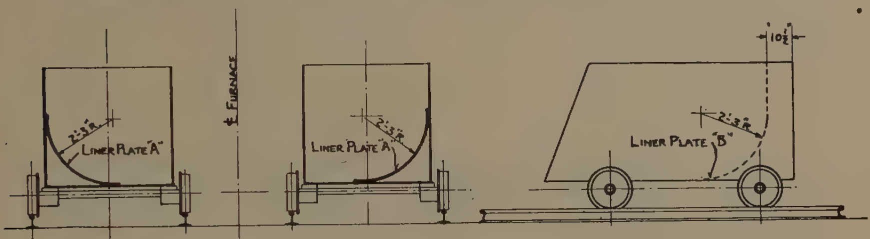


Fig. 5. Sections of skip cars, showing curved liner plates, "A" and "B."

opposite sides of the bins, thus balancing up the extreme irregularity that would have arisen from filling the bucket always on one side. In more recent years this system of filling has been improved by installing a rotating mechanism on the bucket car, which rotates the buckets continuously while charging, or rotates it through a definite angle after each charge, thus endeavoring to obtain an equal distribution of lumps and fines in every sector. While the Neeland type was one of the first mechanical top filling methods, and proved to be a success, the large majority of blast furnace plants have adopted the two-skip system.

Skip Cars

Skip cars may contribute considerably to the effort to gain uniformity in the arrangement of the materials in the furnace. In order to further prevent lumps from segregating, and insure good distribution, each individual operator must carefully determine the proper location of skip while dumping, the angle of tilt necessary, and the speed of dumping, which will best suit his conditions.

The skip should be designed to prevent ore sticking in it, and should be so constructed that in case, with the

volume method of charging coke, it is wished to change the coke unit, the alteration will be simple to make. Figure 5 shows the method of using curved liner plates in the skips at Carrie Furnaces. Liner plate "A" is for the purpose of throwing the materials toward the center line of the furnace, and we believe this feature is of good advantage in distributing the materials evenly in the receiving hopper neck. Liner plate "B" is for the purpose of preventing the materials, especially ore, from sticking to the skip.

Distributing Machinery on the Furnace Top

The first mechanical system of charging, excepting the Neeland type, gave but little consideration to the proper distribution of materials. Later, however, the importance of this feature was realized, and many methods have since been devised to produce an equal distribution of the materials in the furnace. These may be divided into two classes—the stationary and the revolving top. Mr. Vreeland's excellent paper on "The Distribution of Raw Materials in the Blast Furnace," read before this Institute in 1916, gave an able discussion of the various types of tops in use, and the different methods by which they seek to attain the proper distribution of materials.

We use the stationary top on all our furnaces, and Figure 6 shows the latest development of this type of top at our plant. It will be noted that the dumping rail of the skip incline swings in a radius about the center of the front wheel on the skip, allowing the skip nose to remain in the same location while dumping, which we believe insures better distribution of lumps and fines; also the skip nose is held back from the center line of furnace and allows the material to fall more nearly along that line.

The receiving hopper is made as steep as possible to prevent material sticking in it. The hopper neck is made sufficiently long, with its certain diameter, to insure it holding all of one skip; this preventing materials from laying up on the side of the receiving hopper and follow-

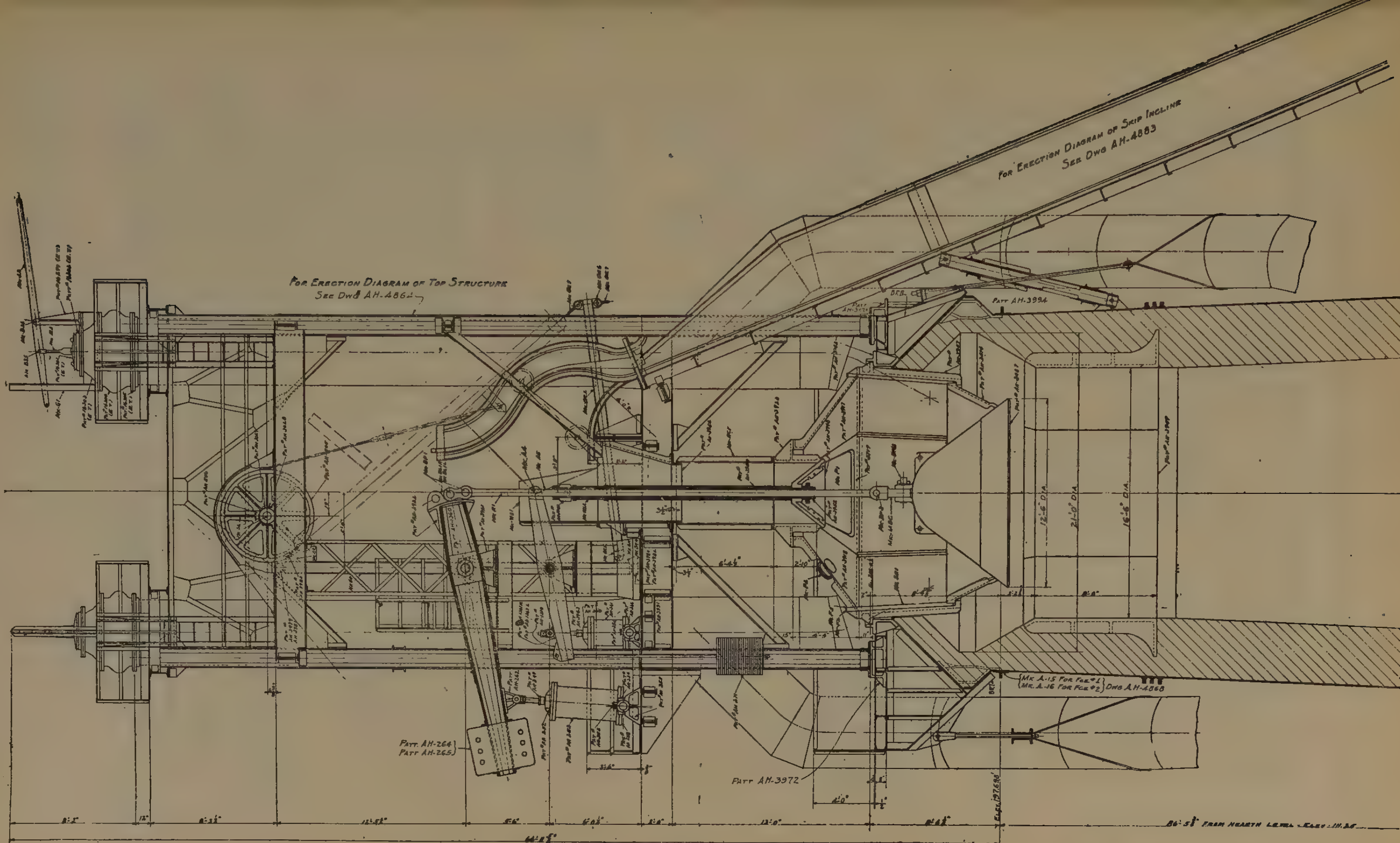


Fig. 6.—Arrangement of stationary top at Furnaces 1 and 2.

ing that side when the small bell is opened. The space between the small and main bells is sufficiently large to hold a full charge of four ore and four coke, with a coke unit ranging up to 14,000 pounds.

The main bell rod suspends from a series of links passing over a curved surface whose center is the main bell lever fulcrum. This eliminates side motion of the bell in its descent due to the radial action of the bell lever. The bearing stands for both bell levers are designed so they may be moved in any direction. This enables us to move the bell levers if at any time the bells are not hanging central with the furnace. The main bell has a slope of 53° to insure the materials sliding off freely, and the stock line is provided with a heavy cast iron protector, made in six sections, bolted together, having a wide base for resting on the brickwork. This type of top has given very good results at Carrie Furnaces. All our furnaces are equipped with distributing machines of this general type, and the two oldest on the present linings, No. 3 and No. 4, have produced 996,856 and 1,028,128 tons respectively. Their individual performances over this period are:

	Fce. No. 3	*Fce. No.* 4
Average tonnage per day,	494	495
Gross Coke per ton Pig,	2083 lb	2055 lb
Coke Screenings „ „	66	69
Net Coke per ton Pig,	2017	1986
Average Loss,	2.74	1.67
Average Blast Temperature,	988°	1013°

These tops have given very little trouble, and but a small amount of time has been lost on our furnaces due to repairs on the distributing machinery. Also, there have been no extraordinary repairs, such as renewal of the stock line, etc.

The modern revolving tops have proven satisfactory at a number of plants. However, I would not recommend that type of revolving top which is so designed that the distribution in the receiving hopper neck is admittedly uneven to begin with, and which seeks to eliminate this unevenness by rotating and discharging each skip load a

fixed number of degrees in advance of the preceding one, but rather would prefer a type giving fairly good distribution even in case it was not rotated. Such a type would, in my judgment, be much better, as the unequal distribution of the stock would be much less to begin with, and it therefore would have considerably more chance of attaining good distribution.

One of the most important improvements to the distributing machinery in recent years has been the electrical operation of the bells in conjunction with the skip hoist. Cables run from the bell levers to the hoist house where the electrical mechanism is generally installed, and the bells are operated by means of these cables. The controls of the skips and bells are interlocking, and the bells can be made to operate in a predetermined sequence with the skips. By this means, a check is had upon the correct sequence of each charge; also the bells open at a fixed rate of speed, which cannot be obtained with steam cylinder operation. Another good feature of this method is the elimination of the possibility of having the small bell left open when the skip dumps, or prematurely opening the small bell, which would allow the materials to run out of the hopper neck on one side of the bell and thus be distributed very unevenly on the main bell.

We do not have electrically operated bells at Carrie Furnaces, but have installed a magnet at the lever of the small bell operating valve which prevents this lever being operated until the skip has been dumped, thereby eliminating one of the undesirable features of steam operated bells.

Even after attaining uniformity in the distribution of the materials on the large bell, the best results will still not be produced in the furnace until the proper method has been found of arranging the skip loads of coke and ore to produce the most intimate mixture. With the Old Range ores, good results were obtained by a system of filling which produced thick successive layers of coke and ore, but with the fine Mesaba ores now in general use this

practice has the effect of forming dense layers of ore through which the gases are no longer able to penetrate and do their work of reduction. This point is well covered by Mr. Vreeland's paper, from which I quote the following:

"With the results for the years 1902 to 1907 before us, during which period the percentage of fine Mesaba ores was on the increase, it is readily seen that our general blast furnace practice was going backward. Many changes were made in design, equipment and practice. Among other problems attacked, the question of filling received considerable attention. During that period the thick strata of materials were used quite extensively. Practice demands that a certain amount of ore must be deposited close to the furnace wall to prevent too much gas following this path. If the theory is correct that a more intimate mixture of the ore, coke and limestone would permit of a better reduction of the ore, because of the more intimate contact of the ore and the gas, due to the more uniform distribution of the gas, then the proposition resolves itself into the adoption of a system whereby we get the requisite amount of ore against the wall, and the remainder of the ore, coke and stone intimately mixed and uniformly distributed over the entire area.

"This system of charging was effected by filling and operating the bell as follows—assuming, for illustration, a 15,000 pound coke charge.

7,500 lb coke on large bell—½ stone and ½ ore	Dump same into furnace.
7,500 lb coke, ½ stone and ½ ore on large bell.	Dump same into furnace.

"The first section gives us a thin layer of coke practically uniform in thickness over the entire area of the furnace, with the ore and stone intimately mixed and deposited close to the walls, some of the lumps rolling towards the center. In the second section, the coke is placed on the large bell and the ore and stone intimately

mixed on top of it; and, upon lowering the bell to deposit the charge, it is observed that only a small part of the coke leaves the bell before the ore and stone begin to break through and mix with the coke falling from the large bell into the furnace. As this section lies in the furnace, it is found that we have a very thorough mixture of ore, coke and stone throughout the entire layer."

With the same idea in mind as that explained by Mr. Vreeland, we changed from a system as follows:

4 skips coke on large bell	—Dump same into furnace.
4 skips ore and limestone on large bell,	—Dump same into furnace.

to this system:—

2 skips ore on large bell. 2 skips coke on large bell. 2 skips ore and limestone on large bell. 2 skips coke on large bell.	Dump same into furnace.

At the time this change was made (June, 1915), all our furnaces were comparatively new, ranging from two weeks to two years on the lining. They had been giving us considerable trouble, due to slipping, making off-grade iron, with high coke. Immediate results were obtained by this change in the filling; the furnaces became much more regular, the coke per ton of iron dropped, and slipping became a rare occurrence. This type of filling has been continued ever since on these furnaces, and has proved satisfactory at all times. A section through the charge lying on the large bell is shown in Figure 7. This shows clearly the comparatively thin strata of material produced by this method and upon dumping into the furnace the layers are much more intimately mixed than would be the case were they to be put in separately and allowed to follow their different lines of travel, in which case the coke would roll to the center of the furnace and the ore would remain comparatively near the walls. This would result in forming a central core of coke through which the gases would pass, causing excessive solution loss to the coke, and as a consequence the ores would reach the hearth in an unreduced condition.

From a study of the arrangement of the materials on the main bell, as shown by Figure 7, it is evident that the thickness of the different strata depends directly on the size of the coke unit used; therefore, a reduction in the size of the coke unit will produce a reduction in the thickness of the different materials, and will result in a more intimate mixture upon their delivery into the furnace. Any

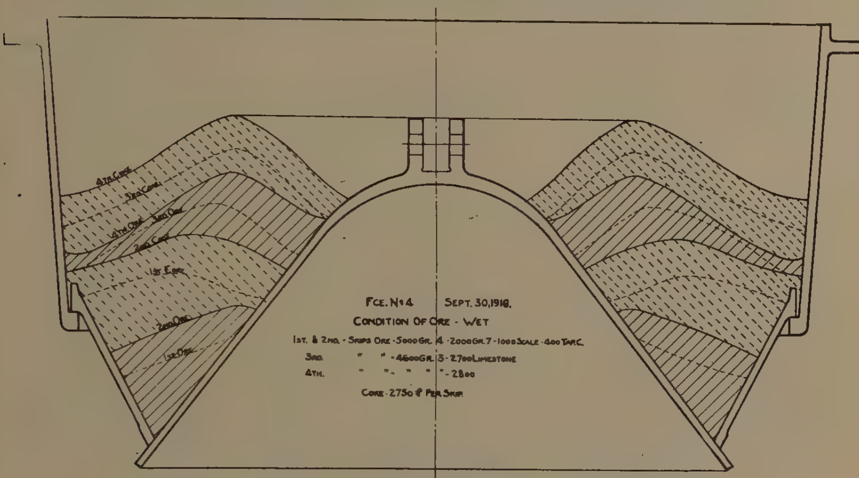


Fig. 7. Section of one full charge o n the main bell.

attempts to realize this benefit must, however, take into account the capacity of the charging machinery to do the increased amount of work that will be necessary. In general, however, it is possible to obtain coke units of from 8,000 pounds to 11,000 pounds, which, I believe, will insure a good mixing of the ore and coke, and result in better working of the furnace than obtains with the large coke units of 14,000 to 16,000 pounds.

I have seen the separate system of filling replaced by the above system, or one similar to it, on furnaces of many different sizes, ranging from 14 feet 6 inch to 19 foot hearth, from 21 feet to 22 feet in the bosh, with bosh angles from 75° to 83°, and heights ranging from 85 to 99 feet, and in all cases the furnaces showed immediate improvement, carried more burden, made better iron, worked very much more regularly, and reduced the coke

per ton of iron; this proving conclusively to me that this type of filling is much more desirable for the present fine ores in use than that which lowers the coke and ore into the furnace separately.

Conclusion

Throughout this paper I have eliminated, as much as possible, detailed descriptions of the different mechanical apparatus used in the charging of raw materials, but rather have tried to indicate the various conditions which must be met by the operator in the handling of the present day raw materials, so as to utilize the existing apparatus to full advantage, because it is my belief that any of the modern apparatus in general use will meet the requirements of the operator satisfactorily if he co-ordinates and arranges the different phases of the charging and mixing of the raw materials so that in their final delivery to the furnace he has achieved the uniformity in their disposition and arrangement that will best suit the various conditions at his individual plant.

Organization and human influence play a strong part in the results obtained by the operator—the different departments must fit well together so that the work performed by them will be a steady evolution of his ideas; the individual must be taught so that he understands the importance of his task, and realizes the results that will be gained through its proper performance, and incentive must be given the individuals to so perform this work at all times in a manner that will be conducive to the general good of the men, the plant, and the management.

Vice-President Topping: We will now have the discussion of the paper, first by Mr. R. W. H. Atcherson.

METHOD OF CHARGING RAW MATERIALS INTO THE BLAST FURNACE

Discussion by R. W. H. Atcherson
Blast Furnace Superintendent, Inland Steel Company, Indiana Harbor, Ind.

The true value of Mr. Mohr's paper can only be appreciated by those blast furnace operators who are expected to produce good pig iron from inferior and irregular raw materials.

Mr. Mohr states: "Irregularities in raw materials can, to some extent, be compensated for or counterbalanced through attention to the various details of the method of charging."

Remarkable blast furnace results have been attained on stationary top furnaces, proving satisfactory distribution for the grade of raw materials used. If their raw materials had been of less excellent quality the need for rotating the top might easily have become a serious factor.

The rotating tops have given excellent results on the Inland Steel Co. blast furnaces. During the present business depression No. 2 Furnace was blown out after producing 1,041,970 tons of iron at a daily average of 525 tons and coke practice of 1,881 pounds. This is not claimed to be a phenomenal record but we were surprised to find that the hearth, bosh and practically all of the stack lining had been worn back very uniformly about five inches.

This furnace had no cooling plates above the bosh. Originally the cast steel T section wearing plates for protecting the stock line only extended 9′4″ below the closed bell. We have put in additional castings protecting the brickwork to 12′ below the closed bell or 8′ below the stock level. All of our furnaces have the same cycle of filling, e.g.:

1 Ore	14,000 lbs.	Dump large bell
1 Coke	3,700 lbs.	
1 Stone	5,000 lbs.	
1 Ore	14,000 lbs.	Dump large bell
2 Coke	7,400 lbs.	

The blast furnaces at several plants in the Chicago district are producing unusually good tonnages and fuel practice. The sequence of filling is not the same at any two of these plants and yet every one of them mix the ore, coke and limestone by dropping them off the large bell together, while the maximum coke mass used is 9,200 pounds.

The successful operation of a blast furnace, especially the life of the lining, depends so much on the regular descent of the column of raw materials and the removal of incipient scaffolds that I believe some reference should be made to the frequent use of scouring or corrective charges of highly siliceous materials.

We recently had an interesting example of the profound effect a change of filling can produce on the internal condition of a blast furnace. Our No. 1 Furnace had produced 700,000 tons of iron since being partially relined. The bosh angle is only 77½ degrees, so that we no longer had a furnace that could be changed readily between radically different grades of product. A couple of months ago we changed from basic iron to high silicon foundry iron, filling a number of orders above 5% silicon. Considering all operating conditions, the results on foundry grades were creditable. Orders were finally received to put the furnace back on basic iron; the usual methods were employed for changing the product but the furnace would not respond to any of the changes sufficiently to operate normally on low silicon, low sulphur iron. All the scouring methods used for cleaning out a furnace were employed, even including fluorspar. The burden was varied widely in amount and composition. The slag was altered through a range from very fluid to viscous slags. Every practical combination of tuyere size, wind volume and blast temperature were resorted to and

yet the furnace would not operate regularly except when we swung over to foundry grades. Finally various standard methods of filling were tried with indifferent results, until we experimented with a more thoroughly mixed charge than I had ever before had occasion to use. The results obtained by the present method of filling have been of such value to us that I believe other blast furnace operators would be benefited by adopting a similar change in their filling, in case they should ever be unfortunate enough to drop into so deep a rut. The following rather peculiar sequence of furnace charging constitutes three of our standard charges:

Ore	12,000 lbs.	Dump large bell
Coke	3,700 lbs.	
Stone	5,700 lbs.	
Coke	3,700 lbs.	
Ore	12,000 lbs.	Dump large bell
Coke	3,700 lbs.	
Ore	12,000 lbs.	
Coke	3,700 lbs.	
Stone	5,700 lbs.	Dump large bell
Coke	3,700 lbs.	
Ore	12,000 lbs.	
Coke	3,700 lbs.	
Ore	12,000 lbs.	Dump large bell
Coke	3,700 lbs.	
Stone	5,700 lbs.	
Coke	3,700 lbs.	
Ore	12,000 lbs.	
Coke	3,700 lbs.	

In this case, where the furnace worked well on foundry iron and miserably on basic iron, it would appear as though we were unable to shift the fusion zone limits without scaffolding the furnace, until we thoroughly mixed our charge.

I would like to add to Mr. Mohr's testimony that I have seen mixed filling substituted for stratified filling at a number of blast furnace plants using Mesaba ores, with beneficial results in every instance. The gaseous current or indirect reducing agent of the furnace physically as well as chemically seeks the particle of ore which it is destined to reduce and it is only by the proper mechanical preparation of the charge that the intimacy of contact is afforded to produce the most efficient blast furnace practice.

METHOD OF CHARGING RAW MATERIALS INTO THE BLAST FURNACE

Discussion by Harry S. Braman
Superintendent, Blast Furnaces and Steel Department, Youngstown Sheet & Tube Company, Youngstown, Ohio.

Mr. Mohr's paper on the "Method of Charging Raw Materials into the Blast Furnace" is a comprehensive account of the different systems used in handling air, coke, limestone and ore, and should be of vital interest to every blast furnace man. Nothing in the practical operation of blast furnaces can cause so much continued inefficiency as their improper handling. In endeavoring to review some of the points brought out in Mr. Mohr's paper, I have taken the liberty of describing their application to the Youngstown Sheet & Tube Company.

Method of Charging Air

The air supply of our four furnaces at East Youngstown is furnished by four horizontal Tod engines and one turbo-blower. As the outside air is freer from moisture and other impurities than the air found in the engine house, the intake was placed outside. Until recently the air intake was a general intake for all furnaces. However, we noticed that with this arrangement the engine on the end of the line was apparently receiving under the same conditions a better supply of air. In other words, the engine nearest the intake seemed to be robbed of its full air supply. A series of experiments were conducted to determine what discrepancies might exist. These experiments plainly indicated that our No. 1 Furnace engine was receiving approximately 7% more air than the engine nearest the intake. We give below our actual tonnage and coke consumption on No. 1 and No. 3 Furnaces, operating under almost identical conditions, for a period of six months. These results seem to verify

the experiments and we have accordingly made arrangements to have a separate intake for each engine.

	No. 1 Furnace		No. 3 Furnace	
	Average daily tonnage	*Average lbs. coke per ton of metal*	*Average daily tonnage*	*Average lbs. coke per ton of metal*
November	584	1,999	555	1,951
December	607	1,976	572	1,983
January	594	1,925	542	1,959
February	589	1,839	557	1,955
March	609	1,696	544	1,866
April	571	1,816	524	1,882
Average	592	1,875	549	1,933

Bins for Ore, Flux and Fuel

The Hoover-Mason bin system for the handling of stock has proven very satisfactory. In this system, the coke, ore, limestone and other miscellaneous material are all handled through the larry cars and dumped into a single revolving bucket, which in turn carries the material to the top for further distribution. Since accuracy in weight of materials is absolutely essential, we have welded the rails underneath the larry car so as to give very little chance for any variation caused by irregularities in the track. The cars are also equipped with tapes which record the weights of the different materials as they are being drawn into the car. These tapes are taken off each morning and carefully checked.

Although all of our coke is handled through our larry cars and their weights recorded, we much prefer the volume system, and accordingly fill the car level full regardless of the weight. There are good arguments on both sides of this question, but our results have been so much more satisfactory with the volume system that we prefer its adoption. The coke for all furnaces is made on our Koppers ovens and transported direct to the furnace by a high line road which delivers it to the bins in transfer cars.

The weighing of ore for each charge to the blast furnace is also an important operation. We have adopted and used generally at our furnaces a system by which

each load of ore is identical in weight. There is less chance for error in weighing large quantities than in weighing small percentages in one charge. The table below illustrates our charging blackboard. This system can be used for any number of ores and percentages, ranging from 5% to 100%, in multiples of five.

	1	2	3	4	5
20% of No. 1 Ore	1		1		
30% of No. 2 Ore	1			1	1
10% of No. 3 Ore		1			
40% of No. 4 Ore		1	1	1	1

Our charge is as follows: Ore, 30,000 lbs.; coke, 14,000 lbs.; stone, 6,000 lbs.

In our method of filling, we use two buckets of ore, two buckets of coke, and one bucket of limestone, which includes each round, and five of these rounds comprises one grand round, thus giving a uniform mixture of the different percentages. The advantages in this method are many over the old method of weighing each ore in each round, particularly. First: More accurate weighing, due to a larger amount of ore, which will not be affected so materially by a slight error in the scales. Second: Fewer trips necessary, less power required, and less wear and tear on the machinery, due to fewer stops and starts. Third: Speed in filling.

Distributing Machinery on Furnace Top

The dumping of the bell also enters into the careful operation of furnaces, and we find by alternating the periods of lowering that good results are obtainable. Following is the method of lowering the bell:

1st Coke	Dump bell
1st Ore	Dump bell
2nd Coke	Dump bell
2nd Ore and Limestone	Dump bell

Two complete charges are filled as above and the third charge as follows:

1st Coke	Dump bell
1st Ore	Dump bell
2nd Coke	Dump bell
2nd Ore and Limestone	Dump bell

This mode of filling is kept up for a few weeks, at the end of which time the furnace may act lazy and seem to lag behind, not taking the number of charges it should. At this point we change the filling as follows, which seems to give the furnace renewed activity.

1st Coke 2nd Coke	Dump bell
1st Ore 2nd Ore and Limestone	Dump bell

This method was arrived at after several months experimenting with the various charges. We noticed that each new change seemed to be better than the one previously used, so the conclusion was drawn that a change in charging at regular intervals gave better operations than any fixed method, probably due to the fact that each new charging gave different paths of resistance to the gas, which resulted in cleaning the furnace, so to speak, and allowing freer working conditions.

The Neeland Top which was incorporated in the design of our furnaces, has given us excellent distribution. We have, however, made a few minor changes in the original design and feel that by so doing we have increased the efficiency to some small degree. Just recently we have blown in No. 2 Furnace which has been down for relining, and prior to our lighting up, a careful inspection was made of the stock as it lay on the top ready to descend for the process of reduction. Coarse and fine materials were evenly spread about and very little variation in the levels of the stock was noticeable. Barring furnace irregularities which might occur, we feel that the stock placed evenly on the top should descend intact and make for better furnace operation. The water-cooled wearing

plates which are in use, are such that they remain unaltered throughout the life of a furnace and are something which can be absolutely depended upon. At times we have lost the water on individual plates due to a crack in the casting near the bottom, but this condition will not necessarily destroy the usefulness of the plate. It does, however, limit the amount of cooling effect according to its proportion of the entire circle. These plates have been used continuously for the past ten years. They are made of cast iron with a pipe coil cast in and are about 6′8″ long, 2′11″ wide, sixteen (16) of which form the complete circle. Examination of two of our furnaces which have been in steady blast for four years and already have a total production of 864,395 tons (daily average 562.7 tons) and 851,988 tons (daily average 547.9) respectively, shows that the stock is still being distributed in a satisfactory manner.

As mentioned before in this article, I have confined myself to our local practice, but have done so with the idea that most every one is interested in what the other fellow is doing, and by comparison of results we all derive benefits. Mr. Mohr has said many interesting things in his paper and brought forth much food for thought, which I believe adds to the progressiveness of the business.

Vice-President Topping: The next discussion of the paper is by Mr. R. V. McKay.

METHOD OF CHARGING RAW MATERIALS INTO THE BLAST FURNACE

Discussion by R. V. McKay
Superintendent, Blast Furnaces, Bethlehem Steel Co., Steelton, Pa.

In taking up the discussion of Mr. Mohr's most interesting and instructive paper, the writer will treat the general subject from the viewpoint of an Eastern furnace operator, laying stress perhaps upon varied local conditions which at times tend to modify, to a certain degree, methods which have become accepted and standardized at plants working exclusively on Lake ores.

At the present time among the four furnace plants of the Bethlehem Steel Company, one is operating practically 100% on Cuban ore, a second exclusively on Lake ores, a third entirely on Cornwall ore, and the fourth mostly on Lake ores, with some New York State and some Cuban ores. With changed after-war conditions, two years from now, the ore mixture at all but one of these plants is likely to be radically altered. European, Cuban, Chilian, and New York State ores, with low-cost water transportation, might easily prove more attractive than Lake ores with their high transportation cost due to long rail haul.

With such unsettled conditions to face, the furnace operator becomes deeply appreciative of the importance of the many fine points which Mr. Mohr has brought out in his treatment of the subject of charging raw materials into the blast furnace. To successfully meet the change when it becomes effective, the very best known methods and mechanical devices should be in use, and all the details of charging air, fuel, ore and flux should be worked out minutely so as to enable the operator to devote study and attention more freely to the problems resulting from change in chemical properties, physical coarseness or refractoriness of the new ore mixture.

Charging of Air

At none of our furnace plants is any attempt made to use dry blast. The Sparrow's Point furnaces due to their location on tidewater encounter the worst moisture conditions, the moisture for considerable periods in the Summer months running 12 to 14 grains per cubic foot.

The majority of the Steel Plant furnaces of the Bethlehem Steel Company use clean gas in the stoves, and therefore, no difficulty is encountered from the accumulation of dust in the blast mains. In the new furnace construction at Steelton, especial attention was paid to the reduction of friction of the blast passing through the mains by the use of extra large hot and cold blast pipes.

The subject of unequal distribution of blast among the various tuyeres is the source of considerable annoyance at many furnaces. At times we have endeavored to correct such a condition by a change in dimensions of tuyeres, with more or less success.

In general, however, better results are obtained from a revision of the filling conditions either as to quality of coke, coarseness of ore, or details of top distribution. With other conditions fairly normal, low grade coke, either extremely dense, or of soft character, is perhaps the chief source from which irregularities of air delivery at tuyeres are derived. Poor coke by causing scaffolding and subsequent bosh slides, or by burning slowly or unevenly, results in some tuyeres delivering more air than others. Such conditions are relieved by changes in top distribution but the proper place to attack the problem is at the coke ovens. Many irregularities of filling can be counteracted by the use of good quality coke.

Charging Coke

Regarding the matter of stationary coke screens, the writer's experience with screens of various types has led to the adoption as standard of a cascade type screen made up of short chilled cast iron segments. These are tapered in two directions thus giving wedge shaped open-

ings which never clog up. If pieces of small coke tend to stick between the bars, they are soon forced along to a wider place where they fall through or proceed down the screen surface. The cascade feature jars the coke lumps, thus shaking off any fine material which may adhere to the coarse coke. When considering a revolving screen, the perforated drum type with coke passing over the outer surface for screening is very effective.

The practice of charging coke by volume is in general use in all but one plant of the Bethlehem Steel Company. All plants use by-product coke, but due to varying facilities for quenching and screening coke at the ovens, the moisture content and percentage of breeze is irregular; therefore, there is a decided advantage to the volume method. The extreme difficulty of properly determining coke moisture in order to make corrections if the direct weight method is used, together with the simplicity of the volume method, causes general adoption of the latter.

Charging of Ore

The charging of the ores normally available for Eastern furnaces is more or less complex because these ores are so radically different, one from another, either physically or chemically. There is very little difficulty in deriving a well graded ore of uniform analysis from each mining district, because most of the ores, aside from Lake ores, are subjected to mechanical treatment, such as crushing, concentrating, nodulizing or sintering, before being further mixed, to a greater or lesser extent, by successive handling in transit to the furnaces.

However, when these ores are collected at the furnace to form the furnace mixture, one finds magnetites and hematites, coarse and fine ores, dense and porous ores, refractory and easy smelting ores, sticky and free flowing ores, so that when an effort is made to correct errors or difficulties characteristic to the handling of one kind of ore, the charging of the next ore may be entirely upset. As a rule, these ores, except for some Lake grades, are

of uniformly low moisture content, therefore free flowing and very easy handled and controlled from stock yard to skip buckets. But their action when discharging from the skip cars on top of the furnace till they are deposited in the furnace is not so easily controlled. On this account, some type of mechanical distributor is indispensable to the Eastern furnace operator. One might develop a stationary top that would distribute one or a certain group of ores, but to meet any possible combination of ores, the revolving top or the rotated skip bucket system is essential.

One plant of the Bethlehem Steel Company is equipped with the latest style Neeland filling system, a second has McKee tops, a third the Baker-Neuman top somewhat modified, and the fourth plant has one furnace using a Roberts top, a second furnace filled by a non-rotating bell bottom dump car, and two others with single-skip simple top. Good distribution is obtained in each case, but direct comparisons are difficult due to difference of operating conditions.

The writer agrees with Mr. Mohr in his statement that a revolving top furnace to be entirely satisfactory should be designed so as to give good distribution when used without revolving, or as a simple stationary top. This generally means a long receiving throat of small diameter, a small bell of corresponding diameter, and the proper position and angle of dump of the skip car when discharging onto the small bell.

The first double-skip furnace at Steelton was of the stationary type, built with no specific data covering the conduct of the materials to be charged. In fact, the furnace was built for Cuban ore practice, but before completion European war conditions cut off the foreign ore supply and the furnace was operated during the first blast entirely on Lake ores. Just previous to blowing in, a platform was built at the stock line and divided into four sectors. Skips of coke and various ores were dumped into the furnace top and then the portion falling into each

sector was weighed and sized. From the beginning it was apparent that there was no uniformity in the conduct of the different materials. Deflector plates were placed in various positions on the side of the receiving hopper and further tests conducted, but whereas a condition of perfect distribution could be obtained for the coarse and fine coke, the baffle used would not serve for the ore, thus requiring a second plate. Finally, with two deflector plates in place, the materials began to hang up, and it was decided to remove all baffles and blow in the furnace.

After two months of very unsatisfactory operation the furnace showed a hot spot on the side opposite the skip. A revolving top was ordered and installed four months later, and immediately a tremendous improvement resulted, in spite of the fact that one side of the furnace lining was entirely gone. An average increase of 1,400 tons of pig iron per month was brought about by the change, and the furnace remained in blast twelve months producing a good regular grade of iron. Upon building the next two furnaces the tops were modified as to dumping position of skip car, shape of receiving hopper and in other details to benefit from the knowledge gained from the filling tests described above, in addition to being provided with the revolving mechanism. Therefore, we now have tops which give fair distribution when in stationary position and a still better distribution when revolved.

Small coke units, 7,000 to 10,000 pounds, are used at all of our furnaces. The methods of charging the ore, coke and limestone vary somewhat at different plants due partly to the individual operator, but mostly to local conditions. At Steelton, with several ores in the mixture, each skip of ore contains its percentage of each kind of ore. This gives a very intimate mixing of materials, but has the disadvantage of increasing the error in weight of ore due to greater number of fractional weighings, as well as causing slower filling and requiring closer supervision. At Bethlehem, the individual ores are charged in large batches, by rounds, in general along the lines of the

Toledo filling system. Good practice is derived from both methods. At the other plants, using but one or two ores in the mixture, the charging is much simplified.

Vice-President Topping: Gentlemen, this paper concludes the exercises for the day. Before we adjourn, it would seem proper for me to express to the gentlemen who have prepared these excellent papers the thanks of the Institute, and I also desire to congratulate them upon the high standard of their papers.

Has the secretary any further announcement to make?

The Secretary: Gentlemen, we will re-assemble at seven o'clock and sit down at the tables promptly at seven-thirty. Those of you who find that you are not seated in the big room must be satisfied to eat hearty and enjoy yourselves, and then when the meeting is over move into the ballroom; there is lots of space in the galleries and on the floor of the big room. After the feast of the spirit we will have the flow of souls.

The chairman then announced a recess until 7 P. M.

EVENING SESSION

At the conclusion of the banquet President Gary addressed the members assembled as follows:

Thirteen hundred welcomes. (Applause.)

Gentlemen, you must feel very proud of the American Iron and Steel Institute. You who have seen it grow year after year for the past nine years must be surprised at the wonderful success which it has achieved. You have made it successful by your unwavering loyalty to the principles for which the Institute stands. (Applause.) We may properly pledge ourselves anew to the support of these principles.

We are all very grateful upon this occasion that the circumstances today are so much improved over those of one year ago. I think we may congratulate ourselves on the fact that the Institute has reached a position of credit, of respect and of influence, and that it has before it a great and profitable future, profitable in the sense of achieving what makes for the welfare of all who are connected with the Institute and of all mankind.

I think all of us are proud to be associated with each other and are grateful for the fact that we are permitted to live at this time and to be connected with such an institution as this.

It is not the privilege of the toastmaster to make speeches. However, you will be entertained and benefited by the speeches which are to be made during the evening.

First on the list which has been prepared and handed to me is the name of one of our brother members, one of the oldest in time of service of the members of the iron and steel industry of this country, one for whom we entertain feelings of respect and esteem and real affection. It is my pleasure to introduce to you our old and much beloved friend, Uncle Joe Butler. (Rising applause amid cheers.)

J. G. Butler, Jr.: Mr. Chairman, ladies and fellow members. I am under instructions tonight to place in front of me a stopwatch. (Laughter.)

When I first agreed to say a few words here tonight, I prepared something. The subject is: "American Steel in the World War." I read it over to Mrs. Butler the other morning to see how long it would take. It took exactly 33 minutes. When I got through she said it was fine. Two or three days after that I got a telegram from Mr. Farrell, the Chairman of the Program Committee, saying that I must not think of taking more than fifteen minutes. I did not lose much time in seeing him. When I came down I told him that that would not do at all, that it could not be done, that what I had prepared could not be read in that short length of time. I also spoke to Judge Gary, and he was very kind, he gave me five minutes; Mr. Farrel gave me two or three, and they finally agreed on 23 minutes as the time I am to occupy.

You know when Rip Van Winkle swore off, he would take a drink and he would not count it. Now, I am not going to count any part of this overture as having anything to do with the speech. (Laughter.)

The Toastmaster: Perhaps I will do the counting.

Mr. Butler: I would like very much if I had the time to say a word of commendation with reference to the splendid address that Judge Gary made to us this morning. His addresses seem to get better and better as time rolls on. (Applause.)

I would like also to say a word in commendation of the splendid papers read and the lantern slides shown to us; they were fine, splendid; but I have not the time to do that. (Laughter.)

I would like to pay a compliment to this splendid audience. Just think of it; I am happy to be here, I can just have a fine view of you, a splendid looking lot of men, engaged in the greatest business in the world—and I am proud that you are here.

I would also like to take time to compliment Mr.

Schwab. He has told me three or four stories. He said I could take my choice and tell any one of them tonight. (Laughter.) They are good stories and I have the matter under advisement. (Laughter.)

Ordinarily I am called on at the close of these enjoyable meetings along about midnight, when people have begun to go home and retire, and all that, but they have honored me tonight with being the first on the program, and they have said that I might read it instead of talking. I took a lead pencil this afternoon in order to cut it down to the 23 minutes, and there are some things that I am not going to read, but Mr. McCleary says the whole thing is going to be printed later on, he is giving me leave to print, and it is possible that it may be given publicity in some other way. Now the 23 minutes commence. (Laughter.)

I hope you can all hear me. If you do not, let me know and I will try and pitch my voice a little louder.

Mr. Butler then read portions of his paper, the full text of which was as follows:

AMERICAN STEEL IN THE WORLD WAR

Joseph G. Butler, Jr.
Vice-President, Brier Hill Steel Company, Youngstown, Ohio

If they are to be estimated at their true values, events must be studied in proper perspective. This perspective extends into the future as well as into the past, however, and it is from the angle of the future rather than of the past, that the World War, ending with the capitulation of the Imperial German Government on November 11, 1918, deserves to be recorded as the most important event in human history.

It is true that this was the greatest war the world has ever seen. Never before was human effort mobilized on so grand a scale. Never were science, skill and physical power combined in like degree for any purpose, good or evil. All of the leading nations of the earth were engaged. The conflict extended to three continents. Battles raged in the air, on land, on the sea, beneath the sea and beneath the land. Directly or indirectly the labor of a hundred million human beings was employed. Six millions perished utterly; fifteen millions were maimed or incapacitated by disease; wealth valued at more than one hundred and seventy-five billions was destroyed, and the productive effort of the most enlightened portion of the human race was for more than four years diverted to tasks of destruction. But all this is no greater than the results achieved. The war has ended for all time the age-old question of the rights of men to self-government. It has relegated to the scrap heap of history the ancient fetish of the divine right of kings; it has opened the way to self-determination of their own destinies by all peoples, and made possible the sweetening and enriching of life for the generations yet to come.

What nation and what element played the pre-eminent part in this epochal event? Many nations may justly

claim each to have made the triumph of the Central Powers impossible. Belgium held the Teuton hordes at Liege and Namur while France and England, both unprepared, aligned their forces for the struggle. France hurled them back at the Marne and stood like a rock throughout the war. England swept the seas of German commerce and flung her armies half around the world. Russia divided the menace at a time when it would otherwise have been overpowering. Italy held the back door of France. But none of these did more than to prevent the ultimate triumph of despotism. With all of them the war might have ended virtually in a draw. It was reserved for America, and above all, American steel, to win the Armageddon of the modern world.

This was a war of steel. Men and food, heretofore the determining elements of military power, were helpless without steel—steel in unlimited quantities and in innumerable forms. The vast armies engaged and the wide ranges of the conflict only served to emphasize the importance of steel. And it was this fact that made Germany and her allies so formidable.

Skill and resources for the production of steel are more highly developed in Germany and in the United States than in any other countries of the world. Their combined production at the beginning of the war exceeded that of all other nations. In America this development was the result of conditions and circumstances none of which were inimical to the peace and safety of the world, but in Germany it seems to have been brought about as a part of the long planned ambition to extend German power and influence by the sword. Until the forcible annexation of Alsace-Lorraine, Germany had but little iron ore, and even the mines of that stolen territory did not meet her needs at the beginning of the World War. In 1913 she imported from France, Sweden and Spain more than 12,000,000 tons. Her production of pig iron in 1913 (figures for that year alone being available) was 19,291,920 tons. With this, and the added pig iron output

of Austria-Hungary for that year, Germany entered the war with an annual production of 21,672,784 tons of iron.

The annual iron production of England, France, Belgium and Russia during 1913 was 22,502,819 tons, and, considering the relatively large proportion of unrefined iron consumed by certain industries in Belgium, it is safe to say the war opened with the Central Powers and the Allied nations about equally supplied with steel. Had no other sources of steel been available it is probable that the war would have been of short duration, for although Germany's ore supplies from France and Spain were at once cut off, this had been foreseen and provided for by the militarists who planned the conflict.

The violation of Belgium and the immediate occupation of that section of Northern France containing practically all of her ore and blast furnace equipment, gave Germany a vast additional supply, while at the same time depriving her enemies of nearly half of theirs. Within three weeks after the war opened, Germany was in possession of the Longwy and Briey iron basins, in which were located ninety-five of the 123 blast furnaces on French soil, together with ninety per cent of all French ore. Very soon also Germany had possession of the blast furnaces and mines of Belgium, and had added to her resources for the production of steel 7,000,000 tons of iron, at the same time reducing the resources of her then enemies to less than 15,000,000 tons. Russia's small production was not available on the Western front at any time, and before long ceased to be a factor. England needed all she could produce, and France was reduced to the minor output of the small St. Etienne fields, with what she could secure from Spain and Algiers under transportation conditions almost impossible, and for the smelting of this she had no furnaces ready. It is evident that under these circumstances the steel production of the allies was less than half that of their antagonists and that, unless this condition were speedily remedied the war must end in the triumph of Germany.

As quickly as the French saw that they could not dislodge the Germans from their ore basins, they turned to this country for steel. At first, it was believed that the Germans, driven back in the first battle of the Marne, could not hold long on the Aisne, and it is likely that if the French had been as well supplied with munitions then as they were later, this would have been the case. Toward the end of 1914 both France and England realized the situation and orders for steel in large quantities began to come to this country. At first the orders were chiefly for barbed wire, shell and shrapnel bars. Later they assumed almost every form in which steel is sold as either finished or semi-finished material.

At this point it may be well to digress from the subject to state that at the beginning of the war its magnitude and probable duration were grasped by very few people, either in Europe or America. The Kaiser had fixed its duration at six months, and even those best informed could not conceive of a conflict that would involve twenty-four nations and last for more than four years. Lord Kitchener was almost alone in his belief that three years would be required to defeat Germany. Neither was the war recognized at first in its true light. Americans generally were inclined to regard it as merely a recurrence of the jealous quarrels that had prevailed from time to time among European nations, and were slow to concede that this country had any interest in the outcome. As time went on, however, and the methods deliberately adopted by Germany to win, together with the purpose her leaders had in mind, became revealed, sentiment in this country underwent a rapid and decisive change.

I was a member of the Industrial Commission sent from this country to France in the autumn of 1916 with the purpose of studying conditions there. This Commission was composed of business men and the principal task of its chairman seemed to be the preservation of an attitude of strict neutrality among the members. With

more or less difficulty this attitude was maintained by a majority of the Commissioners, although I am not ashamed to say that I was not one of this majority. I am likewise proud to state that other representatives of the iron and steel business in this country shared my views. Nevertheless, at that time we were not at war with Germany, and few of our people had yet visualized the conflict on the other side for what it proved later to be—a life and death struggle between democracy and autocracy, in which not only human liberty, but also christian civilization, as distinguished from the essentially pagan system known as German Kultur, faced the possibility of destruction.

It is now a matter for congratulation that the iron and steel producers of America gladly responded to the appeals of France, England and Italy for steel, so supremely essential to their defense. Nevertheless, it is probable that, in the state of public sentiment at the beginning of the war, we should have sold steel to Germany as readily as to France and England, had that been possible. It was not possible because Germany, in violating Belgium, had forced England into the conflict, and England's majestic fleet speedily made the seven seas a highway open only to allied and neutral vessels, preventing shipment to Germany of any materials that could be employed in the prosecution of the war. Later, when the situation became better understood, and long before our government yielded to the pressure of public sentiment with its too long delayed declaration of war, American steel manufacturers had been so aroused against the treasonable and uncivilized methods of the Central Powers that it is doubtful if they would have furnished steel for the German armies under any conditions.

As stated, the part played by the American iron and steel industries in the war began early in 1915 with the filling of rush orders for munitions material from France and England. The previous year had been one of marked

depression due in part to the financial disturbance caused by the war, and the output of pig iron was only 23,332,244 tons as compared with 30,966,152 tons produced during 1913. During December of 1914 production reached a very low ebb, being estimated at between 25 and 30 per cent. of capacity for mills and furnaces. With the coming of European demand and the somewhat better prices following its appearance, conditions changed rapidly, and in May of 1915, when war orders became a veritable flood, production reached about 80 per cent. of capacity. The industries strained every nerve to meet the unusual demand, and by December, pig iron production in America had attained a rate of 38,000,000 tons per year.

That much of the astounding energy shown by iron and steel producers during this period was inspired by higher motives than mere profit is shown conclusively by the fact that during 1915 prices advanced but slightly, the increase in the price of Bessemer iron being only $5 per ton, an amount hardly sufficient to account for the rapidly growing costs of operation. A large amount of the steel produced during 1915 went abroad, but a revival of industrial activity in this country increased domestic demand materially, and considerable steel was used in the making of munitions for the Allies in hundreds of establishments on this side of the ocean.

The year 1916 was a duplicate of the latter part of 1915, except in the matter of low prices. During that year steel and iron exports, the greater part of which were for war purposes, reached a total of 6,101,134 tons, as compared with exports for the previous year of 3,532,608 tons. Prices advanced rapidly, frequent wage increases were granted, and the industry reached a highly prosperous condition. Pig iron production in 1916 was 39,434,797 tons, up to that time the largest on record.

The flood of American iron and steel and their products to France aroused the ire of the Germans, pointing as it did to the failure of their plan to conquer Europe by seizing the iron ore fields and the furnaces of France and

Belgium. Attacks by German submarines on our vessels became frequent. Violation of international law and outrages patently meant to terrorize America were the rule. The sinking of the Lusitania on May 7, 1915, with many other occurrences, made it evident that America would find difficulty in remaining neutral. The administration hesitated and delayed, in spite of suggestions that it prepare the country for defense. Finally, however, a survey was authorized to determine the resources of the nation in the event of war, and the iron and steel industries were asked to furnish information as to their equipment and product. This was done without hesitation, of course; but the most striking evidence of the high patriotism of the men engaged in this industry was the almost universal offer of their plants and resources to the nation. Many of them, convinced that war was inevitable, incorporated at this time a clause in their contracts, making such contracts contingent on "the necessities of the government in time of war or national emergency."

The last half of 1916 and the early months of 1917 were marked by continued activity in the industries under discussion. They also revealed facts concerning the dishonorable methods of German diplomacy and a continuation of lawless insolence that made the possibility of continued peace seem more and more remote. Finally, after apparently exhausting every resource to avoid war, the President called on Congress for authority to use the armed strength of the nation to maintain its rights. The resolution declaring a state of war between the United States and the Imperial German Government was signed on April 6, 1917, and three days later relations with Austria-Hungary were severed. The nation was at war.

Instantly the iron and steel industries, in common with practically all others, enlisted without reservation for the country's defense. Judge Gary, our President, was called to Washington for conference with Bernard M. Baruch, who had been appointed chairman of the Minerals and

Metals Committee of the Advisory Commission, Council of National Defense, and at the mid-summer meeting of the Institute, held at New York May 25th and 26th, the Judge announced that the Secretary of War and Secretary of the Navy had requested him to appoint a Committee on Steel and Steel Products, to aid the government in mobilizing the resources of the country in this line. The Directors of the Iron and Steel Institute had met and appointed this Committee, together with six others to act in conjunction with it and to have special supervision over all branches of the industry. At this same meeting Judge Gary felicitated the manufacturers on the patriotism shown by the industry and announced, among other evidences of this, that the committee had agreed to supply the immediate needs of the army and navy for bars, shapes and plates at $2.50 and $2.90 per hundred—about one-half the prices then prevailing. The tonnage involved was 610,000 tons. Similarly low prices were arranged for the tonnage of sheets and other material needed at once by the government, this having been done in order that the mills to whom this business was assigned could at once proceed to fabricate the steel. It was understood, however, that this extremely low price was tentative and was to apply only to this lot of material, since advancing costs made such prices ruinous. The amount saved to the government by this arrangement was not less than $15,000,000, as the current prices were much higher and demand from all sources was insistent.

From that time forward the government and the industries worked together in the utmost harmony. Prices were advanced to meet rising costs and to provide for the enormous taxes the business was expected to pay. As the machinery of the government was perfected, the iron and steel men were permitted to practically manage their own affairs and they did this with such satisfaction to the government, that J. L. Replogle, Director of Steel Supplies, has paid them a rare tribute since the war closed. Perhaps, however, the best evidence of the high

ideals and genuine patriotism of the leaders in these industries is to be found in the fact that they alone, among all the essential industries, were subjected to no arbitrary regulations and price fixing, but were permitted to work out their own programs and virtually suggest the prices that should be paid for their product.

It is true that certain basic prices were agreed upon between the War Industries Board and the General Committee of the Iron and Steel Institute and publicly announced by the President from time to time. These prices were maximum and were absolutely necessary to prevent what is called a "runaway market." They formed the basis upon which the prices of finished products were computed, but the striking fact of the matter is that the computation was left entirely to the steel manufacturers themselves. As a result there may be said to have been no actual fixing of prices in the industry during the war, as was the case in almost every other line producing material necessary to its successful prosecution.

The only point upon which the government exercised its right to dictate to the iron and steel manufacturers, or found it necessary to even insist on a line of procedure, was upon the question of prices to our Allies. Many steel manufacturers, realizing the enormous taxes they were expected to pay and finding that the prices established by their own committee were very low when these taxes and mounting costs of labor and material were considered, were of the opinion that a free market should be permitted so far as orders from abroad were concerned. The majority, however, approved of the plan to regard our allies in the same light as our own government in this respect, and, as a consequence, although it involved the loss of many millions of dollars in profits, equal prices prevailed.

Largely because of the enthusiastic aid given by practical steel and iron men, many of whom abandoned their own business and voluntarily gave their entire attention

to the government's pressing problems at Washington, a system of allocation for the industries was evolved which contributed much toward their efficiency in the nation's defense. Under this system certain classifications were established, and these were served by the industries in the order of their importance in the great task of winning the war. As a result, practically all the steel manufactured during the period of the war was devoted to war purposes. Of course much of it was not directly so used, but practically none of it was employed for any enterprise by which the conduct of the war was not vitally assisted.

While the iron and steel manufacturers were confronted by a limited advance in prices they continued to voluntarily raise the wages of their men until the earnings of these employees were the highest ever known. The successive wage increases during the three years ending October 1, 1918, totalled considerably more than 100 per cent. Not only that, but these companies bent every energy toward the financing of the war, buying heavily of Liberty bonds and providing the machinery by which their employees could purchase these bonds, and pay for them in small installments. They led all other industries in their contributions to the many funds raised for humanitarian work during the war, as did also the men and women employed in these industries.

Because of the rapid advance of wages in all American industries, and particularly in the steel industry, the wage earners of America were enabled to contribute to the financing of the war in a manner that will always redound to their credit. In Germany, by a complicated and insidious arrangement of the governmental machinery, the cost of conducting the war was met largely without the aid of popular subscriptions to war loans. These were taken to a great extent in that country by manufacturers and merchants, all of whom were permitted to profiteer almost without restraint in order that their profits might be invested in government securities. The

frightful injustice of this system would have been evident had Germany won, but as the event proved, enormous profits wrung from the German people that they might be invested in war loans have mostly turned to ashes, leaving the profiteers as poor as the people. In this country, while the corporations conducting the industries, and especially those conducting the iron and steel industries, invested heavily in government bonds, the greater portion of these were taken by the wage earners. No figures are available for the whole country, but in certain districts employees in the last named industries purchased an average of more than $500 each in the four loans floated in 1917 and 1918. In one large steel plant in the Youngstown District this average reached the astonishing total of more than $600 for each employee.

A feature of the part played by the iron and steel industries of the United States in the winning of the war that should not be overlooked was the tremendous increase in production achieved during its period in the face of great obstacles and with the high purpose of providing the materials necessary for the triumph of our country and its allies. Much of this increase, particularly in certain lines, was made possible by new construction, undertaken in the face of costs that were so enormous as to be absolutely prohibitive if viewed in the cold light of business. The needs of the nation were, however, a compelling argument with these industries. In some cases, government aid and government guarantees were obtained, but this seems to have been only in cases in which the construction was of such a nature as to leave no prospect whatever of its utility after the war.

Blast furnaces, open-hearth furnaces, plate mills, rolling mills and by-product coke plants costing many millions of dollars were hurried into existence long before their time and without regard to cost, in order that the steel, benzol and toluol needed might be made available. As a result of this the steel production of the country had reached, at the time the armistice was signed, the

amazing rate of 47,000,000 tons per annum. Plate-making capacity alone was increased during 1918 to 7,500,000 tons per year. The output of shell steel was similarly augmented. The expense and uncertainty of investment, as well as the increased capacity that must certainly involve complications after the war, were apparently lost sight of. The steel industry had only one object—to produce as much steel as was physically possible in every form in which it was needed to win the war. It succeeded in doing this to such an extent that government officials in a position to know all the facts have publicly declared that no part of the government's tremendous program was halted or delayed at any time because of insufficient steel. No other industry has made a similar record, in spite of the fact that human history contains no story of achievement such as the preparation of the United States for this conflict.

The war is now over. There is reason to hope that history will never see such another. Without American steel, the cause of justice and humanity would have been temporarily lost, and the world must needs have stood at arms for generations to come. The American steel industry has, through its supreme effort in this most supreme cause, placed itself in a position from which it may find difficulty in extricating itself without a period of severe trial. But it will meet the problems that now face it as it has met others in the past, with courage, energy and vision worthy of its majestic power and inspiring history.

A document signed by the executive officers of the leading steel companies in the United States and, by many of them posted in their works during the trying period of 1918, I will read:

Our Pledge

For myself, my corporation or my firm, I pledge the prompt production and delivery of the largest possible quantity of material in our departments that

is or shall be required by the United States Government for the necessities of itself and its Allies, and agree that all other lines of business shall be subordinated to this pledge, and all this in accordance with the request of the War Industries Board.

The executives who signed this pledge personally asked their employees to join them in it. That both corporations and their employees kept faith is shown by the fact that during 1918 American mills produced 44,462,000 tons of steel, and that of this practically every pound went directly or indirectly into the task of winning the war that has, let us hope, made the world safe forever for the weak and life better worth the living for all humanity.

The annual report of the United States Steel Corporation for 1918, made public March 30, 1919, gives the tonnage furnished by that corporation during the war to the United States Government and its allies as eighteen million, four hundred and thirty-nine thousand, four hundred and sixty tons. Based upon the relative productive capacity of the independent mills during the same period, the total amount of American steel used directly for war purposes could not have been less than fifty million tons. From the same information it is evident that the industry as a whole furnished not less than one hundred thousand men for the national service during this great struggle, as well as that its expenditures for increase of productive capacity needed in the emergency must have aggregated more than one billion dollars.

[At the Evening Session of the General Meeting held May 28, 1920, Mr. Butler presented the following data in continuation of his paper on American Steel in the World War.—Ed.]

The manner in which the whole American people responded to the call of country during the emergency arising from our entrance, with almost no previous preparation, into the most momentous struggle of all history, the World War of 1914-18, forms one of the brightest pages in the record of democratic government. The part

played in this inspiring evidence of national strength and solidarity by the iron and steel industries was not less noteworthy than their contributions to the cause of civilization in the form of products necessary to win the war.

The amount of steel contributed to the combined armies and navies of the allied countries during the war cannot be stated with exactness, but a conservative estimate made from the latest information at hand places this at the stupendous figure not less than 100,000,000 tons. Much of this was used indirectly for war purposes and a considerable portion of it consumed in this country. Nevertheless it was a part, in one form or another, of the vast machine by which the war was won.

Fortunately it is possible to present the facts concerning the contribution made by the iron and steel industries in the form of men and money more exactly than those in regard to the tonnage of steel supplied to our government and its allies. The American Iron and Steel Institute sent out inquiries to its contributing membership, comprising plants of all kinds. The replies embrace reports made by five hundred and sixty-eight steel companies in the United States, and include all except a comparatively few smaller concerns, statistics from which would not materially change the totals.

These statistics have been arranged in three groups. The first (see Table 1) shows the number of officers and employees of the companies reporting who were engaged in the service of the United States and enrolled in regular organizations in the army, navy and aviation corps, together with the number who voluntarily engaged in auxiliary war work in various organizations approved by the government. The second group (see Table 2) gives the total subscriptions to Liberty Loans made by officers and employees of these companies, arranged so as to indicate the nature of the securities and the amount of each taken by corporations and their employees wherever possible. The third group (see Table 3) gives in detail for fifty-six leading companies the number of men in

service, the amount of securities purchased by companies and by employees (or by both where this was not separated on the records), and the grand total of subscriptions and enlistments for these fifty-six companies and for all of the companies reporting, 568 in number.

It is worthy of note that the group of fifty-six companies referred to above sent into the service more than 80 per cent. of the total enlisting, and at the same time subscribed about 82 per cent. of the total amount invested in war securities. This group included no companies subscribing for less than a total of $2,000,000. More than thirty-three companies, in addition to these fifty-six, purchased securities in excess of $1,000,000. A striking fact in this connection is the report by all of the fifty-six companies mentioned, that their employees were 100 per cent. enrolled as purchasers of bonds during the war, as well as that the employees of some of the smaller companies whose detailed statement could not be included herewith because of the necessity of brevity, were among the largest buyers of both bonds and war savings stamps.

Reference should be made also to the relatively large number of executives included among those who enlisted in the various branches of the service, as well as to the number of these who won special honor therein. An effort to secure information on this point met with so much reluctance to have individual records made public that the idea of doing so had to be abandoned, but it is a fact that the number of rising young executives who laid down their tasks at the beginning of the war, and even before it actually began, to go to the front, was astonishingly large.

The statistics given below indicate that the iron and steel industries of this country contributed 131,504 men to the service of the country during the war, and supplied funds to the amount of nearly $700,000,000 for the prosecution of the struggle. It is a matter of deep regret that no adequate records have been kept by the greater number of companies concerning the contributions made by them

and their employees to funds for war work, such as the Red Cross, the Y. M. C. A., the K. of C. and other organizations. Comparison of security purchases and war work contributions by companies and their employees in the relatively few cases where accurate figures on this point are obtainable, indicates that the amount furnished for these forms of activity by the steel industry was very nearly equally divided between the employees and the stockholders.

Many claims are made as to who won the war. It is fair to say that American steel played a very important part. It is my intention to endeavor to obtain statistics showing the income tax and all other forms of taxation made upon and paid by the steel producing interests. These figures will show the large sums exacted and possibly aid in the publicity very much needed to contradict the wild stories prevalent of the enormous profits made by the producers of steel.

TABLE 1.—NUMBER OF OFFICERS AND EMPLOYEES OF COMPANIES CONNECTED WITH THE AMERICAN IRON AND STEEL INSTITUTE WHO WERE ENGAGED IN ACTIVE OR AUXILIARY SERVICE IN THE WORLD WAR

Number of companies reporting	568
Number of officers and employees connected with companies represented in the Institute who were in active service with the army or navy, including aviation	130,450
Number of officers and employees connected with companies represented in the Institute who were engaged in voluntary or auxiliary service for war work	1,054
Total number of officers and employees in service for war work	131,504

In addition to the 1,054 officers and employees reported as having been directly engaged in voluntary or auxiliary work during the war, many officers and employees of iron and steel companies devoted much of their time to Red Cross and other similar organization work.

TABLE 2.—SUBSCRIPTIONS TO LIBERTY LOANS BY OFFICERS AND EMPLOYEES OF 568 COMPANIES CONNECTED WITH THE AMERICAN IRON AND STEEL INSTITUTE

War Loans	Amount Subscribed for Company Account	Amount Subscribed for Employees' Account	Amount Subscribed, Unclassified as to Company or Employees	Grand Total
First Liberty Loan..	$ 42,526,440	$20,915,610	......	$ 63,442,050
Second " " ..	98,382,450	37,562,810	......	135,945,260
Third " " ..	86,970,200	52,062,487	......	139,032,687
Fourth " " ..	129,311,670	92,390,180	......	221,701,850
Victory " ..	72,536,350	41,698,050	......	114,234,400
Unclassified* " ..	2,043,500	667,648	$14,397,800	17,108,948
War Saving Stamps..	See total	See total	120,617	120,617
Total.............	†$431,770,610	$245,296,785	$14,518,417	$691,585,812

* Some companies did not state whether amount subscribed was for first, second, etc., loan.

† A number of companies were unable to render reports separately for company account and employee's account. In all such cases, the amounts subscribed have been credited to company account. At a number of iron and steel manufacturing plants, which had large contracts for the government, the government exempted employees from the draft, so that the output of the plants might not be decreased. At other plants the government requested the companies to use every effort to induce employees who were in government service to return to work. In almost all the leading iron and steel manufacturing companies there was a 100% subscription to all loans except the Victory Loan. Many subscriptions to Liberty and Victory loans were made by officers and employees of iron and steel manufacturing companies through local banks. Unfortunately in numerous cases no records were kept of these subscriptions.

TABLE 3.— DETAILS FOR FIFTY-SIX COMPANIES, REPRESENTED IN THE AMERICAN IRON AND STEEL INSTITUTE, ARRANGED ACCORDING TO AMOUNT OF SUBSCRIPTION

Company	Number of Officers and Employees in Active, Voluntary or Auxiliary Service	Amount Subscribed for Company Account	Amount Subscribed for Employees' Account	Amount Subscribed for War Saving Stamps	Amount Subscribed for Liberty Loans, Unclassified as to Company or Employees	Total Subscription for Account of Company and Employees
United States Steel Corporation.	34,613	$116,050,400	$65,600,500	......	......	$181,650,900
Bethlehem Steel Corporation....	17,923	16,357,400	22,300,650	......	......	38,658,050
International Harvester Co......	4,707	15,700,000	9,763,100	......	......	25,463,100
Jones & Laughlin Steel Co......	(a) 2,609	15,585,800	7,507,950	......	......	23,093,750
Midvale Steel & Ordnance Co...	(f) 4,765	8,324,750	9,103,450	......	$4,644,800	22,073,000
General Electric Company......	8,534	(c)	20,317,300	......	......	20,317,300
Republic Iron & Steel Co.......	1,681	11,985,700	4,452,000	......	......	16,437,700
Youngstown Sheet & Tube Co...	2,052	9,000,000	7,159,900	......	......	16,159,900
Lackawanna Steel Company....	1,887	8,000,000	5,270,450	......	......	13,270,450
Confidential report*............	(a) 801	9,219,000	(a) 1,817,650	......	......	(a) 11,036,650
McKeesport Tin Plate Co.......	(b)	(d) 10,560,000	......	......	......	10,560,000
La Belle Iron Works..........	404	7,100,000	1,898,100	......	......	8,998,100
American Can Company........	(a) 3,448	6,000,000	1,900,000	......	......	7,900,000
M. A. Hanna & Company.......	(e) 24	5,125,500	2,468,200	......	......	7,593,700
Pittsburgh Steel Company......	282	5,000,000	2,395,400	......	......	7,395,400
Cleveland-Cliffs Iron Company. .	(a) 584	5,323,000	1,738,300	......	......	7,061,300
American Brass Company......	1,883	7,000,000	(b)	......	......	7,000,000
Joseph T. Ryerson & Sons......	196	(c)	(c)	......	6,478,000	6,478,000
Inland Steel Company.........	745	3,950,000	2,418,700	......	......	6,368,700
Semet-Solvay Company	1,799	4,250,000	2,017,750	......	......	6,267,750
Colorado Fuel & Iron Co........	1,791	2,725,500	3,477,150	......	......	6,202,650
Crucible Steel Co. of America...	1,705	(d) 6,197,050	......	......	......	6,197,050
Brier Hill Steel Company......	497	3,551,850	2,190,650	......	......	5,742,500
American Brake Shoe & Fdy. Co.	223	4,145,000	1,545,750	......	......	5,690,750
Great Lakes Engineering Works.	535	4,490,000	1,128,850	......	......	5,618,850
Shenango Furnace Company....	135	3,318,750	1,949,400	......	......	5,268,150
Allegheny Steel Company.......	361	3,466,500	1,611,250	......	......	5,077,750
American Steel Foundries......	1,147	2,140,000	2,639,200	......	......	4,779,200
Columbia Steel & Shafting Co...	1	4,382,500	380,000	......	......	4,762,500
Alan Wood Iron & Steel Co.....	260	2,862,800	759,600	......	......	3,622,400
Otis Steel Company...........	240	3,050,450	519,550	......	......	3,570,000

*Company name withheld by request.

TABLE 3.—DETAILS FOR FIFTY-SIX COMPANIES, REPRESENTED IN THE AMERICAN IRON AND STEEL INSTITUTE, ARRANGED ACCORDING TO AMOUNT OF SUBSCRIPTION—(*Continued*)

Company	Number of Officers and Employees in Active, Voluntary or Auxiliary Service	Amount Subscribed for Company Account	Amount Subscribed for Employees' Account	Amount Subscribed for War Saving Stamps	Amount Subscribed for Liberty Loans, Unclassified as to Company or Employees	Total Subscription for Account of Company and Employees
American Radiator Company...	779	$2,222,750	$1,290,000	......	......	$3,512,750
American Vanadium Company..	43	3,138,750	(c)	......	......	3,138,750
Wheeling Steel & Iron Co.......	495	2,450,000	682,900	......	......	3,132,900
West Penn Steel Company......	158	2,163,450	927,550	......	......	3,091,000
Union Drawn Steel Company...	202	(c)	(c)	......	$3,075,000	3,075,000
Spang, Chalfant & Company....	278	2,350,000	708,450	......	......	3,058,450
Railway Steel-Spring Company..	281	2,317,000	604,750	......	......	2,921,750
United Eng. & Fdy. Company...	312	2,257,750	652,250	......	......	2,910,000
Trumbull Steel Company.......	335	1,700,000	1,200,250	......	......	2,900,250
American Rolling Mill Co.......	713	156,370	2,685,200	......	......	2,841,570
American Chain Company......	502	1,622,300	1,175,400	......	......	2,797,700
Crompton & Knowles Loom Wks.	497	(d) 2,782,600	......	......	......	2,782,600
Phoenix Iron Company.........	126	2,300,000	325,350	......	......	2,625,350
Vanadium Alloy Steel Company.	42	2,450,000	97,400	......	......	2,547,400
McClintic-Marshall Const. Co....	278	1,489,750	987,000	......	......	2,476,750
Sloss-Sheffield Steel & Iron Co...	690	2,140,000	278,000	......	......	2,418,000
Timken-Detroit Axle Company..	1,206	1,035,000	1,265,700	......	......	2,300,700
Rogers-Brown Iron Company...	33	1,522,000	726,900	......	......	2,248,900
Stanley Works	458	1,189,050	948,000	$92,671	......	2,229,721
Sharon Steel Hoop Company....	528	800,000	1,425,100	......	......	2,225,100
Upson Nut Company...........	260	1,200,000	927,550	......	......	2,127,550
Standard Parts Company......	927	1,318,800	796,850	......	......	2,115,650
The Steel & Tube Co. of America	637	781,600	1,299,150	......	......	2,080,750
Follansbee Brothers Company..	(a) 252	1,158,750	899,400	......	......	2,058,150
Lukens Steel Company.........	(b) ...	1,374,200	677,800	......	......	2,052,000
Total for 56 Leading Companies	105,864	$346,782,070	$204,911,750	$92,671	$14,197,800	$565,984,291
Total for other 512 Companies..	25,640	84,988,540	40,385,035	27,946	200,000	125,601,521
Grand Total...........	131,504	$431,770,610	$245,296,785	$120,617	$14,397,800	$691,585,812

(a)—Not complete. (b)—No record. (c)—Information not given.
(d)—Includes subscription of company and employees. (e)—Cleveland office only. (f)—Includes Cambria Steel Company.

Judge Gary: You who have had the privilege of hearing a large part of this splendid address can imagine how much fun Mrs. Butler had listening for 33 minutes to this speech, so near to it that she could hear every word of it. (Laughter.)

The General Committee of the Iron and Steel Institute did not have in Washington quite so easy a time as Mr. Butler pictures. If everything had been left entirely to the committee I am inclined to think it is possible some of the prices at least would have been advanced from time to time.

When our committee first met the War Industries Board in Washington, they encountered problems which seemed to be very difficult and uncertain of solution. During a whole day's discussion our committee became acquainted with a member of that Board who had realized a very successful business career, a man well acquainted with the different lines of business and who had become a very wealthy man and had devoted a large part of his wealth to the Washington University, of which for many years he had been and still is President. That gentleman was familiar with accounting, and during our many conferences he presented us, sometimes in a degree to our discomfiture, an analysis of the figures made up by the Federal Trade Commission which demonstrated to us that some of the calculations which had been presented by members of the iron and steel industry were not justified: a gentleman of strong convictions, of steadfastness in purpose, of a high sense of loyalty and patriotism, but a gentleman who was always considerate, painstaking, patient and perfectly fair; and during all our intercourse that gentleman, who afterwards became the Chairman of the Price Fixing Committee and was influential in the final decisions which were made, standing impartially between the Government on the one side and the iron and steel interests on the other, aided and assisted in arriving at conclusions which were just and fair and reasonable and which satisfied finally all the members of our com-

mittee, notwithstanding at various times they believed the insistence of the Government was unreasonable and somewhat harsh. At the end of all our conferences that man had secured the absolute confidence of every man connected with the iron and steel industry who had come into personal and intimate relations with him and his committee.

The American Iron and Steel Institute on this occasion is greatly honored by the presence of that very great man, and it is my privilege now to introduce to you Mr. Robert S. Brookings. (Rising applause and cheers.)

Mr. Robert S. Brookings: Mr. Chairman, and gentlemen of the Steel Institute: For a man who has never seen but two steel plants, Bethlehem and Midvale, and those the same day, I feel strangely at home among the steel men.

While my practical experience is limited, I think if the Steel Institute would admit any paper members, that I might try to qualify for membership, because I have had quite a little paper experience. I have mined ore from Lake Superior to Alabama, have mined coking coal in the Connellsville district, in Kentucky and in Alabama. I have operated beehive and by-product ovens, and although you may not believe it, I have even made good furnace coke from low grade Illinois coal by aid of the Roberts ovens—on paper. (Laughter.)

In studying your cost sheets, because the Judge tells you that I have been trading for some period of time, notwithstanding Colonel Butler's remarks, with all of you gentlemen, I wish to assure you, if you are in any doubt about it, that in the selection of this General Committee you put me up against the real thing. It is true we have thought that we had something to do with fixing the prices, but we were met with the spirit that—well, it enabled us to follow our leaders without much difficulty; and in studying your cost sheets, those I suppose of nearly every steel institution in the country, I was naturally very much interested in the disparity of costs and very curious of

course to know the why and the wherefore, so that I have dug into cost details to a point where you have my most sincere sympathy in the problems that I know most of you have had to solve.

As the Chairman of the Price Fixing Committee I have been able to become intimately connected with a number of the metals, all the chemicals, practically all of the textiles, in fact almost the entire field of industry, but have always returned to steel; it had strange fascination for me. I have followed steel into the spindle, the loom, into the machine tool, the locomotive, the cars, into practically every branch of industry that we have had to deal with. It filled my vision to the full; it was the great keystone of the wonderful industrial arch. So that when I came in contact with this special committee of yours, which I did every ninety days, I probably impressed upon them that I had a knowledge of the steel business which, by necessity, was more or less superficial.

I wish to say in a very few words the one thing that brought me to New York tonight: I wanted to express the earnest appreciation of the Government for the broad, patriotic, constructive spirit in which the steel industry received practically every suggestion made by the Government during the war. (Applause.)

I do not know what we would have done without your earnest help in stimulating production, without your assistance in allocating orders, and above all without your voluntary help and assistance in stabilizing prices. I think the Government would have been so frightfully handicapped that it would have been almost impossible to have carried out its extensive war program.

The war is over and of course we are all glad that it is, but I am frank to say that I have missed very much meeting with our steel friends, especially the committee headed by your distinguished Chairman. I have marvelled at the infinite tact with which he has from time to time guided us over the rough points, at how his wise judgment has frequently reconciled apparently conflicting

views and interests, until we were all at one, and for the one purpose.

I am sure that when the industrial history of the war is written it will be a monument to American manufacturers; and standing out in bold relief will be the steel industry, not only because steel was overwhelmingly the most important war need, but because it was first to inaugurate and to lead into that relation between the industries and the Government which has been the marvel of our friends on the other side of the water. (Applause.)

I have read abstracts or extracts from pretty much all the economic journals on the other side; they cannot seem to understand how it was that people would voluntarily do the things that we have done in this country, for instance in food conservation, without any of the drastic laws to which they were compelled to have recourse. Our people, voluntarily, practically in the midst of plenty, surrendered a large proportion of what we possessed for their good. And they especially marvelled at the industries because, as a matter of fact, we had no law, we had no process of law by which we could say to the steel industry: you shall fix a certain price for the public. We could commandeer your product, and in commandeering it we would have become involved in infinite detail and trouble. But when we have stated at all these meetings, "Now, gentlemen, we have no act of Congress that permits us to say that your price shall be so and so to the public; we can commandeer for war purposes, but we have no right except that we do personally represent the President, the Price Fixing Committee is the one arm of the Administration that reports directly to the President and receives its instructions directly from him, and all we can say is that the President, the Commander-in-chief of the Army and Navy, has authorized us to say that we want you to do so and so," it was more potential in its influence than the most drastic law could have been. We have never yet met an industry that under those conditions has not said, "Well, we cannot agree with you,

Mr. Brookings, in the ultimate findings that you have made as to our values, but while we cannot agree, if the President of the United States says that we should do this sort of thing, and you are representing him, you can rest assured we will do it with all the earnestness and all the enthusiasm as though our judgment had been convinced."

That, gentlemen, in a way, has been our Washington experience with the industries of the country, and that has been spread on the minutes of the Price Fixing Committee. As I said before, when the industrial history of the war is written it will be a monument to American manufacturers. (Applause.)

JUDGE GARY: Members of the Institute, especially the young men, will you excuse me for trying to emphasize a point?

You know by the testimony of this sincere man that your representatives in Washington tried to be reasonable and just, and even to the mind of the Chairman of that committee sometimes yielded their opinions against the judgment, at least, of a few or some of the members.

It is not immodest for me to say in behalf of the committee that they believe those assertions are true, and the reason why the committee acted in this way was because the committee was inspired by motives of patriotism for our country. (Applause.)

Now, young men, the wars are over. The occasion for the continuance of these experiences in Washington which have been referred to have gone by. But patriotism has not gone by. (Applause.)

Patriotism still lives; and it applies to every one of us in our everyday business. It is not necessary to have the continuance of a war in order to insist upon the application of principles of patriotism towards one's country. It is a principle which extends throughout all our business relations. I want to say to the young men of the American Iron and Steel Institute that you will find by long experience you will receive the largest

reward if in every particular in dealing with one another, with your employees, your customers, your competitors and the general public, you exercise a feeling of fairness and justice and patriotism towards the whole people of the United States and towards each other. (Applause.)

And so, young men, pardon me for saying that you are coming forward, you are going to take the leading positions in our industry, and you are expected to hold high the flag of honor in all the business which pertains to the iron and steel industry. (Applause.)

The next speaker is one whose voice you are always glad to hear, who has been our constant and consistent friend, who is directly connected with the iron and steel industry as a director and member of the Finance Committee, who is a student in political economy, who is possessed of a mind big enough to grasp the situation and a heart big enough to sympathize with all our difficulties and problems, and who has the courage of his convictions, and is one of the active, influential and valued members of our Institute.

I now present for your attention Mr. George W. Perkins. (Applause.)

Mr. George W. Perkins: Judge Gary, ladies and gentlemen: speaking of the Y. M. C. A., or rather Mr. Schwab, because of course there really is no difference—simply the welfare association in the one case and the Bethlehem Steel Company in the other; and in one case you refer to it as the Y. M. C. A., the Young Men's Christian Association, and in the other case you refer to the organization as an association of Christian young men. (Laughter.)

I have been asked to speak this evening on several topics, from eight to thirty minutes on each topic, and after I really get to a point where I am about ready to start, I am going to do as brother Butler has done and say, "Now I will begin to take my twenty-three minutes." I promise to be brief.

Brother Schwab, you know, has been on the other side,

was there a good part of the time I was there. It was said that he was over there on Government business. He was really there, as I was, in connection with the work of the welfare association. He would speak one night in a Y. M. C. A. hut and the next night in a K. of C. hut, and I noticed as I followed around that whenever he spoke at the K. of C. huts, as he left and went to his automobile to go to the next one, someone would get up and say, "Now, who can tell us the head of the Catholic Church?" and immediately the answer would come back "Charlie Schwab." (Laughter.)

Therefore it is quite natural when I came home to find both the Democrats and the Republicans expecting to nominate him for president. (Applause.)

Then he would go on to a Y. M. C. A. hut and he would say, "Boys, it is outrageous, this criticism of the Y; just let me tell you the things the Y does. Take the ship I came over on. We were chased by a whale. The whale would come uncomfortably close; everything was done to drive it away. They threw all sorts of things at the whale; they threw a box of oranges at the whale and it ate it up; they threw a three-legged stool at the whale and he devoured it; they threw a Y secretary at the whale and he ate him; then they threw two or three soldiers at him and he devoured them; but he kept on following the ship. When we got to Brest the whale was so near that they dragged him upon the shore and opened him, and, boys, what do you suppose they found? There was that Y secretary sitting on the three-legged stool feeding oranges to the soldiers." (Laughter.)

A gentleman said to me the other day. "Do you know Charles M. Schwab?" I said, "It seems to me that I have got memory enough to—yes, yes, I do." He said, "What do you think of his stories?" "Well," I said, "they are very remarkable stories." "Well," he said, "I do not know as I would call them remarkable; but I sometimes get the impression that they are a little mite risque. I will tell you one of them. It topped me a good deal."

If the ladies will pardon the story—they may not think it risque, but I will warrant that every man will consider it risky.

He said, "I understand that Schwab now says that he has in his possession a piece of iron made 40,000 years before Christ." Where he got it from and who the donor was and all that I don't know that he has added as yet. (Laughter.)

The work of the world, gentlemen, it seems to me today is centered in what has happened in this great war, and those of us who have had the privilege to be on the other side have not only seen but felt it in all its intensity.

I am sure Mr. Schwab will bear me out when I say that the thing that stands out today in Europe among the business men and the thinking men and the statesmen as the great accomplishment of the war has been the magnificent, united effort of the steel men of the United States. (Applause.)

Everywhere one went over there, one was questioned as to how you did it so promptly and so efficiently. Not only that, but they marvelled at the lack of friction between labor and capital in your great industry; and it has made such a deep impression that, especially in England today, they are really concerned as to where the supremacy of the steel industry of the future is to lie—and perhaps I put it mildly in thus expressing it.

Now, all that is greatly to your credit. It has been splendidly stated here by Mr. Butler and Mr. Brookings, and I will not attempt to even review it, but use it simply as a stepping stone to what I want to say of a serious vein. It is this: what have we learned from our efforts of the past two years? Is it simply a piece of work done, and are we going back to the methods of the past; or are we going on to the future, to broader, more useful, co-operative methods? That, it seems to me, is the great question of the hour, and that this is the most important meeting you have ever had. What of the future?

In Paris the other day there appeared 36 men, members of the Chamber of Commerce of Cleveland. The Chamber there gave a dinner and asked me to speak, and I made bold to ask those men why they had come to Paris. Of course the answer was: "To look for trade in France." I said, "Pardon me for suggesting that your first trip was in the wrong direction. I challenge your wisdom in coming first to Paris. It seems to me clear that you should have gone first to the City of Washington, with like bodies from other cities, and said, 'Gentlemen, we would like to go to France and to other European countries and look for trade; will you please tell us on what basis we can do that business; are we to be allowed to co-operate and seek trade in that way, or are we to go back now that the war is over to old competitive methods in industry?' "

Now, the world has learned much in this war. The young men of whom Judge Gary has spoken have learned much. Two and one-quarter millions of them have been over there. They have come back very much more thoughtful men than they were before. They are wondering what it is all about, what the new world is to be.

I believe there is no set of men in any country today who are as able to help solve the problem and point the way to these young men as the men who sit in this room tonight.

There is a great mystery and lack of information as to what has happened. The public as a whole does not know why business methods have so greatly changed. What has made it necessary to co-operate rather than to compete? They have a feeling that there has constantly appeared in the world a number of supermen, vastly more able in certain positions than any men who lived before. Judge Gary is one of those great examples. Yet as a matter of fact, with all due respect to his vast ability—and no one, as you know, admires him more than I do—his father may really have possessed more actual native gray matter than his son; but he never in the world

could have accomplished, in administrative ways, what his son has accomplished, because he did not have the machinery with which to do business.

Our people do not realize that we must co-operate, because we are in an electrical age. Only a few days ago a United States Senator came into my office. We wished to talk over a matter with a man in New York. I picked up a telephone and asked my office exchange to get him. The answer came back that the man was in San Francisco. It was about the middle of the afternoon. I said, "Well, get him." The call was put in. The Senator said, "Oh, gracious, what is the use of doing that?" I said, "You wait a little bit and we will see." In a few minutes the call came back that they had the man; he happened to be in the office they called in San Francisco. His voice came on the wire. I spoke to him and turned him over to the Senator. With trembling hands and a startled look he began to talk to his friend in San Francisco. Neither of us had left our chairs. When he finished he said, "Well, talk about your miracles!" I said, "Senator, why do you think I put in that call for that man?" He said, "So we would get the business finished with him." I said, "Not at all. I take every occasion I can to get every one of you men who are making our laws about business to realize that you have not much, if any, conception as to what the underlying, fundamental machinery of business today is. Here you talked without moving from this chair to the man in San Francisco, who did not leave his chair. Your bodies no longer have to be transported in order to commune between your minds, and yet you pretend to say we have got to keep apart and to do business in the old fashioned method."

Now, coming to my point about what you can do: I believe if those 36 men from Cleveland would go to Washington and talk earnestly with the men there, who for the most part are not men of business, and give them the reasons why they must be allowed to co-operate, and similar bodies of men would go, from Pittsburgh and other

cities, that we could soon have co-operation between business and politics that would bring very beneficial results.

I believe further that we should no longer hesitate in our meetings, of whatever nature we attend, to express clearly in homely, straightforward language to the people, the situation as it has so vastly changed.

If this Senator that I speak of did not realize, as he did not, what the telephone has meant in the line of business methods, how do you expect the man who is simply in an office or in a store to know the first thing about it?

We are today discussing a League of Nations. Whatever form that may be in and whatever the differences may be among us as a people, we all of course want peace if it can be had. But, gentlemen, there is another issue quite as immediately important, and it is a league of classes, by getting together in a better understanding between capital and labor, in which progress no set of men have done so much as you, a league of classes to discuss the great, new, economic, fundamental principles, that have made the vast changes in our business fabric.

Now, you know those reasons. The people do not know them, the politicians do not know them, and I believe the patriotic duty of this organization is in the immediate future to undertake that educational task.

I thank you. (Applause.)

JUDGE GARY: Time is passing, but do not think, do not believe it is eleven o'clock, simply because your watches tell you so; it is only ten o'clock. (Laughter.)

It has been our privilege on several occasions to hear from a gentleman whose acquaintance and friendship we value, and who also resides in the great City of St. Louis; he has lately been abroad and had an opportunity of seeing something of what is going on there. I will now call upon that gentleman, Mr. Clarence Howard. (Applause.)

MR. CLARENCE HOWARD: Mr. Toastmaster, ladies and gentlemen: It is a great pleasure to be here tonight after

my return from abroad, because I received a great deal more and better food than I got any time I was on the other side. (Laughter.)

I remember with great pleasure when you gentlemen were all in the City of St. Louis, and I hope you all left there with a feeling that you some day would want to come back, and I want to say that the invitation is now extended and we will welcome you any time that you are ready to come back, and we will endeavor to do better than we did before.

In regard to my trip abroad I would like to tell you a few things that I saw and heard. A question has been asked me several times, just why did I go. I sailed on the 27th of January. I was on a committee of the League of Nations, in which I am deeply interested, and I believe I see through it the prevention of war, or at least a round table discussion to prevent many things before war takes place.

Then I wanted also to look into the establishment of a Commonwealth Steel Co. office in Paris, which I did. Also before going over I had a talk with Mr. John R. Mott, who from my experience has proven to be one of the greatest men of this age along the line of human engineering. In all our energies and everywhere we have brought out the best engineering in the world along mechanical and other lines, but we have failed in our colleges and in our institutions to take a deep interest in human engineering. We need humanics as well as mechanics, and that day has arrived, and instead of our being away up here some place and the other fellow way down there we have got to get on that footing of human thought and relationship which brings the office boy and the president on the same basis, to work it out together.

While I was in Europe I had that impressed upon me more deeply than ever and proved my idea of Bolshevism. When one of the boys told me, "We are here in the trenches, there is the rich man and the poor man, the labor union man, the non-labor union man, all together,"

and they simply wiped out all of the differences and were brothers in the sense of true fellowship. When anyone needed help they were there to help him, it didn't matter who he was if he was really trying to do what they were all there to do, to establish true democracy in the hearts of men throughout the world. And when we go back and ask ourselves, "What is democracy?" we find two thousand years ago a man who established true democracy and who put as a foundation under that democracy the Sermon on the Mount, he keystoned it together and he said it would always stand, and it is standing, and on that basis we won the war. It was the spirit, the American spirit, of the boys that did win the war, and this boy said, "This fellowship we have established in the trenches will never die out, not in a million years." That is encouraging. Mr. Mott said to me, "I believe you have no strings tied to you, political or otherwise, and you can tell me just what you find; I want you to tell me as you travel over there, what you find in the Y. M. C. A. work."

Now, I have been, for my station in life, a very liberal contributor, and everything that I saw and everything I judged, convinced me more and more than I had been, of the magnificent investment; and it increased in value as I saw the work being done, and especially in the army of occupation in Germany.

In Coblenz there are thirty-seven different activities and they are doing a splendid work for the morale of our boys. While there I was given a—let me see if I have got it; here—I was given an Iron Cross, and the man who gave it to me said that the officer he took it away from didn't need it any more and I might have it.

These little German kiddies, with their little square heads used to come over to our American barber shop to get their hair cut and our boys are just as foolish about them as they can be, and they cut their hair, but it got to be a nuisance, so that they had a council of war and said, "What shall we do?" So they picked out a handsome

little kid, put him in the chair, laid an Iron Cross on the top of his head, and shaved the balance of his hair, leaving him with the Iron Cross of hair, marking him up and letting him go, and they did not have any more trouble with the kiddies.

But the one inspiration of my life was when we arrived in Coblenz, one of the first men I met was a bright, fine looking soldier boy about six feet tall. He came across the street and said, "Aren't you Clarence Howard?" I said, "Yes." He told me his name. I used to carry him when he was a baby—a boy; I will not tell you how old he was, because you will get on to my age—oh, well he was twenty-eight years of age, and he was a captain in charge of the military police and was absolutely running that little burg, conducting the traffic and everything, and doing it in a magnificent way; and if anyone thinks that the American boy is not running that part of Germany he is mistaken.

Later we drove around on inspection. We came to a great barrack where the Germans used to parade and have music, and guard mount; there were not any Germans inside; there were a lot of them on the outside, but inside there was one of the most handsome, well trained, well behaved set of splendid American boys in guard mount, with their fine band playing American music. They marched down in front of the Kaiser's Palace. He had a beautiful palace with a beautiful front yard, and he happened to leave two spots on each side of the walk, and the Y. M. C. A. built two great fine huts, one of them was feeding ten thousand doughboys a day, and on the other side was a gymnasium. Then they marched down further, and I only saw perhaps twenty soldiers in uniform, and they were officers; one of these officers had to step aside to let our boys by, and saluted them. Then I looked over my shoulder and I saw the greatest fort in the world outside of Gibralter, with the American flag flying over it; and I want to say to you

that if that scene would not make an American's blood tingle I do not know what will. (Applause.)

As we went up through the battle lines, we went outside of the regular traffic and saw many of the trenches and places of camouflage, exactly as they were the day the armistice was signed: they are now fast taking down all of those and filling the trenches. I saw more barbed wire entanglements and more barbed wire than I ever saw in the world, and I had the pleasure of seeing many, many thousand German prisoners building up what they tore down and filling up the trenches that they had dug—and that was a whole lot of pleasure. (Laughter.) But I didn't find any of the German prisoners working as I thought they should, until we came across a bunch of fifty with three darkies from Missouri in charge. (Laughter.) They had them on the job all the time.

Now, I took occasion to go to a great many of the Y. M. C. A. huts, I had a number of very fine pictures, and I talked to the boys, right heart to heart, and I went to Tours and Chaumont, and all up through that country, and I found everywhere most excellent work being done by the Y. M. C. A. and particularly by our women. I never saw such sacrifices and splendid work. I found a Miss Ely, her father was superintendent of motive power of the Pennsylvania Railroad, way up in the edge of Germany with a wonderfully crude Y. M. C. A. hut; but that little woman's touch—she had given all the boys who had been there eighteen months a banquet the night before, and one of the boys who told it says, "You talk about your banquet: why, it was from soup to dessert," and he was just simply delighted; and so, all the way through, the spirit of our boys was wonderful.

At Tours I went over to where the railroad people were, General Atterbury, whom you know, Fred Delaneaux and Colonel Nutt—the fellows said he had to be a Nutt but he wanted to be a kernel—and all the way through, I took occasion to go to a hut that night and

talk to the boys, and there was a thing there that touched me about as deeply as anything ever has. I talked to the boys about their mothers and how they should come back pure and clean and wholesome, and I do not know just what I said, but I spoke to them along those lines. When I got through a great, fine soldier came up to me and touched me on the shoulder and he said, "Mr. Howard, you don't know me nor anything about me, but I could not go out of this hut tonight without coming and taking you by the hand and thanking you from the bottom of my heart, first for making me homesick and second for making me think very seriously of my mother, and you have done for me something that you little know," and he said, "I wish I had something to give you that would be in keeping with what my heart would say;" then he went in his pocket and pulled out that little piece of shrapnel and he said, "Mr. Howard, there is a little piece of shrapnel that almost cost me my life at Chateau Thierry," and he said, "I want to give it to you;" and I will tell you, gentlemen, that was a very touching thing, and if I did nothing else on my trip to Europe I would feel I was repaid by that one night's work.

I could tell you fifty stories, but I know they have got the watch on me and I have only a few moments, but I could talk to you by the hour of that trip and of the splendid condition of our boys, the splendid spirit, the manly ways and all. I come back home so much better an American; I love this country so much more. And yet I say the day is here when there will not be any divisions in any part of the world, and we will be at home everywhere and we will love each other and we will learn to love, as we love each other in this country, throughout the world. There is not any reason why we should not. It is just a matter of education and helpfulness and I believe that our boys going over there has done that great work for the world.

Now, I want to say just a word: I was very much interested and deeply touched by what Judge Gary said

tonight to the young men, it is one of the best things I have heard in years, and his talk this morning was very helpful, very inspiring and very comforting to all of us whose plants are pretty near shut down, because we all believe that it is only a short time until business will be revived in good shape, and for such men as he and Robert Brookings—and by the way, I just want to say that Robert Brookings raised me from a boy and I want to say that I love him dearly and I have known of him since I have known anybody, and in St Louis he is loved by all of us boys. (Applause.)

Now, I want to diverge a moment. June 14th is Boy Scout week, and I want you to permit me to say just one word. I am President of the Boy Scouts of St. Louis. We have had the boys only from twelve to eighteen; then I got together the boys from eighteen to thirty and joined them into what was known as the Junior Citizens; the same Robert Brookings gave me a fine big building for the headquarters of the Junior Citizens and the Boy Scouts, and, when the Third Liberty Loan was called for, those boys went out and got $6,000,000 worth of Liberty Loan bonds from that headquarters, and they have been doing that sort of work all along. We have not been taking time enough, any of us, to give the fullest consideration to the boys, and as the Judge said these boys become young men and then they become older and take our places, and therefore we should put our arms around them and help to guide them so that they will be in better position to take our places when the time comes.

Now, recently we have gotten these boys as Junior Citizens into the Junior Chamber of Commerce, and one year has proven that it is a great success. I believe that that will be one of the coming things. Now, these boys from eighteen to thirty, 300 of them, when the call came, stepped out and went to the war, and they are just returning home now. At that time it was half of the membership of the Junior League, but they are going now to fight for America. They have conceived the plan to

have an associate membership for the Boy Scouts, and that week they are going to have to bring about that condition, and I hope that we will all make a study of it and see what we can do for the boy life of this country.

I thank you. (Applause.)

JUDGE GARY: At one of our meetings we had the great pleasure of listening to a very eloquent speech by M. Knecht of Nancy, France, and fortunately he is with us again this evening and we are going to ask him if he will speak to us again. (Applause.)

M. KNECHT: Mr. President, ladies and gentlemen: In 1917 I had the great honor of bringing to you a message of thanks from my chief, M. Andre Tardieu, the French High Commissioner to the United States. That message thanked you for the splendid co-operation of the steel industries of the United States with the steel industries of France and especially with the Government of France.

I remember that on that evening at the Waldorf-Astoria we were wondering what would be the future and we were asking if perhaps the two swords of America and of France, swords made with your iron and with your steel, would win the war.

We have won this war with iron and with steel. We have won it with you, and I associate my thanks to the thanks of Mr. Robert Brookings: France is thankful to you for your wonderful help and also for the generosity of your prices when the prices were settled on the same basis for all the allied governments. (Applause.)

I wish to add that the iron of Minnesota and of Alabama, the steel of Ohio and of Pennsylvania, liberated the iron of France which was lying deep in the soil of my native province, Lorraine; it is through you that we have it back again, and I think that it will be of interest to you to know that the present Deputy Minister of Industrial Reconstruction, my friend M. Le Brun, the well known Deputy of the District of Briey and of Logwy, in 1915 while serving as an artillery officer was obliged to shell with his artillery, his beloved mines of Briey, his

native town; and I remember him describing to me his anxieties that night and that day when he was watching the results of the French shells ordered by him, falling on those mines which the genius of his people had contributed to render prosperous in those last fifteen years!

M. Le Brun, in 1909 before the war, had foreseen the great events which were to happen. He said in 1909 that there was a political frontier between one part of Lorraine and the other part, but the underground—and this is curious to examine—the underground from Nancy, France, towards Metz, at that time in Germany, was only one line of iron, it was the same vein of iron ore; we had next to it the salt, and the salt extended from France to Lorraine in Germany, it was also one mine of salt, only the same salt mines prolonged on the other side; and in another material, the coal which we found in the Moselle Valley in France, extended into the Saar district.

Now, we see that this frontier, which was only political, has been broken. Now all these iron mines are together; they are French again; we are going to try to rebuild them because, as you know, they have been terribly destroyed and all the steel furnaces of French Lorraine have been completely ravaged, ruined, and there is absolutely not one furnace remaining in the Longwy and Briey Districts. How are we going to do it? Gentlemen, this is one of the most interesting problems of French reconstruction. We are going to rebuild them, but we are going especially to use those which were on the other side, those which were on the Metz and Thionville side, which belong either to French capital or to German capital, and which are to be given us in exchange for those which have been utterly ruined by the Germans. Germany had decided that they would keep the mines in order but that they would destroy the furnaces; these furnaces were no longer needed, they belonged to French capital, and it was quite enough to keep in a greater Germany the furnaces which were situated on the Metz and Thionville side.

And what proves to you that the action will be taken, the same French High Commissioner, M. Tardieu, who was delivering to you a message two years ago, has been the one who under the order of the peace delegates has been drafting the final clauses of the peace treaty relating to the Moselle and Rhine provinces; it is Tardieu, who, knowing this better than any man in France, has been able to grasp the situation, to give justice to us—only justice, because you, American friends, must remember one thing, that this peace treaty we have obtained through your iron, we have to see concluded and conformed to justice as France and America have always wished. But we must execute it also with a will of iron, because if Bismarck and Hindenburg had been dictating the peace to France it would have been not a will of iron but a treaty of iron, and this is a treaty of justice. (Applause.)

You must remember the sacrifices of the years before, and we must remember in our international vision of justice, gentlemen, that we have to be as just to those who suffered as to those who give suffering to others. (Applause.)

We face a very dark situation, for you know and you ought to know, you have just read these last days the remarkable statements of Mr. Davison and of Mr. Vanderlip, and I hope you will hear more from them because they have seen and they have judged with a remarkably clear sight. Our economic situation in France and Belgium is bad and is worse than the German economic situation. This must be known. It is a very interesting fact. France has won a very great moral and spiritual victory—it will remain immortal, and we are proud of it, and we prefer to have won a moral victory than to have attained a material victory—but still we have the right to try not to have a material defeat. We are now nearly at material defeat, but still we have friends in the world, and we have our energy and we have our decision and we have the sacrifices of our population, and we have the pleasure of thinking that this American flag which is

floating in Coblenz is also floating next to the French flag which is in Metz and Strassburg. (Applause.)

And outside of that we know that we have to look only to this country to find and feel your example in financial matters, in practical matters. We have to rebuild with a new spirit of enterprise and business, and the country which has given to this war men of the initiative of Joffre and of Foch can also produce in the next several years civilians of the same initiative, men whom we can compare with joy and pride to men like Judge Gary, like Mr. Farrell and like Mr. Schwab. (Applause.)

In our darkness we have seen a star these last days; we have seen a star which is like the star of Bethlehem, which is like the star which the population of France saw in the sky of the United States when Pershing and his first crusaders arrived on the shores of France to save civilization and liberty. (Applause.)

The same star we saw when Wilson, when Clemenceau and when Lloyd George had at last the vision of nominating Marshal Foch as the head of the allied armies. (Applause.)

The star is a star which will interest you, because it is your own life, it is your own soul, it is your own profession. The 16th of May this year must remain indelibly printed in the memories of all the steel institutes of the world; on the 16th of May in the invaded districts of France, where we had only ruins, burning houses, trenches, tombs, with hundreds of thousands of dead—of America, of England and of France—M. Loucheur, our very able Minister of Industrial Reconstruction, and M. Le Brun, Deputy of Briey, have solemnly put fire again, given fire again to one of the furnaces of a steel plant destroyed by the German armies when they were passing through northern France. (Applause.)

We have seen again bright fire in the furnace and the workmen of France under the leadership of engineers of France joyful to see at last French steel coming out of the furnace and showing to the world that France,

though very much crushed under economic defeat, is now again alive and will live—and will live with your help, with your friendship, and will live eternally to prove that the steel men of France are able to go on and to follow the example of the steel men of the United States in the war.

Gentlemen, we have won the war through steel. We are going to win the peace through a will of steel, and we must keep the peace, develop it, maintain it and create this great brotherhood of humanity. It will not come very fast, because before human nature is perfect we have to work hard and to change many things, but still let us hope, all of us, you Americans and we Frenchmen, that some day we will be able to unite together for the welfare of humanity, and before that let me hope on behalf of France and on behalf of my friends of the steel industries of Lorraine, perhaps next year, perhaps in July—on the 4th of July when the French flag and the American flag will float harmoniously in France, the Iron and Steel Institute of America, under the leadership of Judge Gary, will visit those iron and steel plants and those mines of Lorraine which the bravery of the American soldiers has given back to the Republic of France. (Applause.)

Judge Gary: The representatives of the iron and steel industry are not hasty in making promises; but they are great in performance.

It will be our pleasure to co-operate with the French in every reasonable way in carrying on the great work which the spirit of harmony has brought between the French and the American people. (Applause.)

Gentlemen, what is your pleasure?

(Cries of "Schwab," "Schwab.")

Judge Gary: I told him so. Mr. Schwab. (Great applause.)

Mr. Charles M. Schwab: Mr. Chairman, ladies and gentlemen: I live in the country, up at Loretta. An old farmer there came to sell me a cow the other day and he said, "Now, Mister, I think you ought to buy this cow." "Well," I said, "is she a pedigree cow?" "Well, no,"

he said, "I cannot say that she is." "Well, how many gallons or quarts of milk does she give each day?" "Well," he said, "Mister, I cannot even tell you that, but," he said, "one thing I do know, that she is a good, willing old cow, and if she has got any milk she will give it." (Laughter.)

Boys, I have not much of anything to say to you. I said to Judge Gary, "Adjourn it, and let us get home"; and then upon second thought I said to myself, "Well, now, I would like the opportunity to eulogize George Perkins." (Laughter.)

You know, he took it out on me. George is really a great man. I don't know why he was made Chairman of the Finance Committee of the Young Men's Christian Association. But one time I visited Austria, just before we thought of them as our great enemies, and the Emperor said to me, "What are you doing in this country?" I said, "Looking at the iron and steel works." He said, "What can you find in this little country, after your great works in America?" I said, "Your Majesty, I can at least see what to avoid." (Laughter.)

Now, that is about the only reason that I can think of for Perkins being connected with the Young Men's Christian Association. (Laughter.)

You know, George was a great help to us, though, in the Steel Corporation. He has a real right to belong to this association, not only because of his experience but because of his technical knowledge of the iron and steel industry. One time we sent him to Paul Morton, when the Judge and I were new in the game down in Wall Street or down in Broadway, to sell some rails that we wanted to sell pretty badly, and George went to see Morton, the president of a railroad, and insisted upon his buying these rails from the Steel Corporation, and Morton said, "Why, yes, George, but there is the Lackawanna Steel Company, they promised to give me rails with .3 phosphorus." George said, "I don't give a damn how much phosphorus they put in, we can put in just as much as anybody." (Laughter.)

And then his technical knowledge extended even to mechanical appliances. One time he met Dr. Unger. You all know Dr. Unger, he has got a lot of technical knowledge about the iron and steel business, and he talked to George for a long time and George came to me and said, "Do you know, I am going to bring up before the Finance Committee of the United States Steel Corporation the appropriation, after listening to Dr. Unger, of a large sum of money, to buy a bifurcated spout for the open hearth." (Laughter.)

George thought that that was some great new process or plant, but we fellows who know something about the steel business call it a common, every day spout.

But notwithstanding all that, George is a pretty good fellow. He has had it in for me ever since I had that dream in Chicago. It was a dream. (Laughter.)

There are some smart fellows in the steel business, you know, though, and when I see Replogle—after he told that story about Grace and me, I always feel like letting him in for the full amount, if I can. He is a smart fellow. He is about the only fellow I saw in the whole assembly up there today who had the sense to go out and buy some steel stock after the Judge made his speech.

I had the pleasure of presiding this afternoon during the Judge's absence, during a very learned discussion on a technical question about sonims or something of that kind, and I have been puzzling my brains ever since to know what in the world this thing was; but I finally came to the conclusion that Joe Butler, noting that they had a lot of those sonims in the Brier Hill steel, was enabled to sell lower than anybody else. (Laughter.)

I knew it was some good, technical reason; it would not have been any moral lapse upon Joe's part; but that damned sonim spoiled the price of that Brier Hill steel.

Now, gentlemen, just to be serious a moment: I, too, have been to Europe; Mr. Perkins has been there and Clarence Howard has been there. They represented the great Young Men's Christian Association institu-

tions. Well, I did, too. I said to them something that they won't forget for many a day. But to be serious, one of the most interesting visits that I had there was the pleasure I had meeting the great French Marshal Foch, and I said to him as any real American or citizen of the world would have said, that which was uppermost in my heart, the thanks and congratulations of every man for the wonderful work he had done, and he said to me, "My dear friend, the general staff and command of these great armies was like a great orchestra and each instrument had to play its part in harmony with the whole great orchestra, and the baton which fell in my hands was but a matter of fate and chance; it was the collective and co-operative work of all that won this war." I thought to myself what a lesson for the great institutes and industrial communities of this country, and especially the Iron and Steel Institute.

Let us work co-operatively to sustain the honor and the credit that we have won in the great world war. Let us stand by each other and work together as we worked during this war. There are lots of material steel makers in the United States, men with material and sordid minds, but those from Bethlehem, in addition to making steel, have within themselves a deep sentiment and love for the business, as well as their fellow men; and I want to say to you that as friends whom I cherish, cherish as long as life may last, cherish as Shakepeare says in the quotation in this program, to such an extent that I will grapple you to my soul with hooks of steel, let us feel towards each other and act towards each other in this period of reconstruction in this highly idealized and sentimental character, and greater security, prosperity and happiness to the world and to the industry will result.

I thank you for your kindly reception. (Applause.)

Judge Gary: With thanks to all of you for your presence, with thanks to those who prepared such splendid papers for this meeting, and thanks to the speakers of this evening, who have entertained us so satisfactorily, I bid you good night.

OCTOBER MEETING

NEW YORK CITY

OCTOBER 24, 1919

Photographic Reproduction

OF THE

Presentation Volume

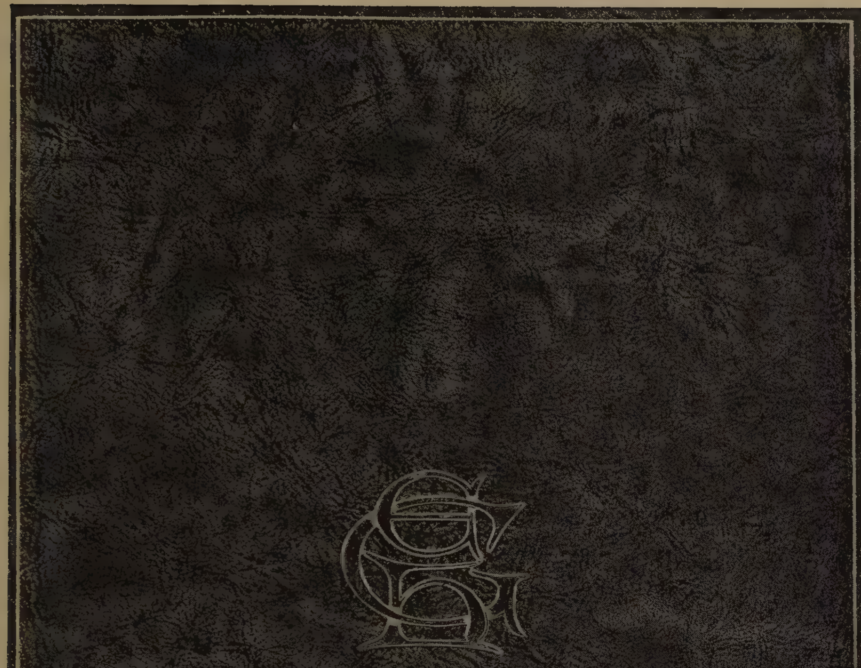
TO

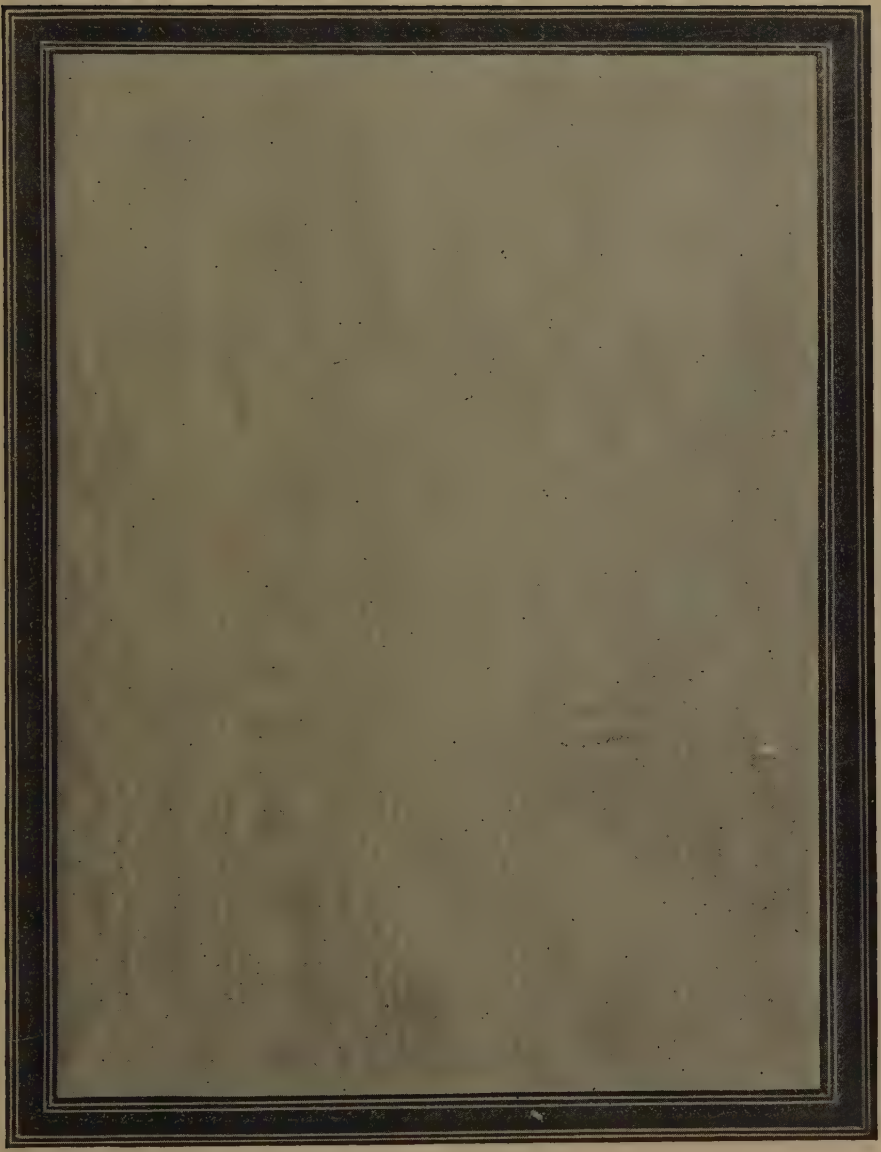
ELBERT H. GARY

President of the

American Iron and Steel Institute

Containing the
Resolution Passed at the General Meeting
October 24, 1919





At the Sixteenth General Meeting of the

American Iron and Steel Institute,

held at the Hotel Commodore, New York, on Friday, October twenty-fourth, nineteen hundred and nineteen, with Mr. Willis L. King, Senior Vice President, tem-

porarily in the chair, Director Joseph G. Butler, Jr. of Youngstown, Ohio, presented the following resolutions, which were unanimously and enthusiastically adopted, everyone in the large assembly rising and applauding most heartily:

Whereas,

Elbert H. Gary

President of the American Iron and Steel Institute, has rendered to

the American people and the American iron and steel industries a service of inestimable value by his course as a representative of the public in the Industrial Conference at Washington; therefore be it

Resolved, That the American Iron and Steel Institute, assembled in its semi-annual meeting, hereby records its unqualified approval of Mr. Gary's firm stand against any infringe-

ment of the rights of the individual in labor or in business, rights fundamental to American industrial supremacy as well as to American liberty; that it admires the vision and courage enabling him to discern and effectively oppose the radicalism injected into trade unionism by unscrupulous leaders, an element especially dangerous under present conditions, when world-wide unrest has created an opportunity for agita-

tion aimed at the perpetuity of institutions under which our country has achieved its strength and our industries attained their efficiency and prosperity.

Directors

Secretary

AMERICAN IRON AND STEEL INSTITUTE

SIXTEENTH GENERAL MEETING

NEW YORK, OCTOBER 24, 1919

The Sixteenth General Meeting of the American Iron and Steel Institute was held at the Hotel Commodore, New York City, on Friday, October 24, 1919.

Following the usual custom, three sessions were held. The forenoon and afternoon sessions, held in the East Ballroom, were devoted entirely to the reading and discussion of papers. The evening session, which included the semi-annual dinner, was held in the Grand Ballroom. The papers and discussions were concerned chiefly with problems of metallurgy and business.

At the evening session the Institute was honored by the presence of Albert, King of the Belgians, and his suite. A reproduction of a recent photograph of His Majesty will be found as frontispiece to this volume.

At the morning session, following the address of President Gary, Mr. Joseph G. Butler, Jr., of Youngstown, Ohio, offered a resolution, which was unanimously adopted approving Judge Gary's stand on the labor question. The Directors of the Institute later had this resolution embodied in a book, with the resolution engrossed on parchment with illuminated hand-work in color. A photographic reproduction of this presentation volume will be found opposite this page.

On the following page will be found the program of the meeting. Judge Gary, President of the Institute presided at the morning session and until the close of Dr. Howe's paper in the afternoon. Mr. Willis L. King, Vice-President, presided during the remainder of the afternoon session. Vice-President King also presided for a short time in the morning session during which Mr. Butler offered his resolution. Judge Gary acted as toastmaster at the evening session.

PROGRAM—OCTOBER MEETING

FORENOON SESSION, 10.00 A. M.

Address of the President.............................ELBERT H. GARY
Chairman, United States Steel Corporation, New York.

The Work of the Bureau of Mines.....................VAN H. MANNING
Director, Bureau of Mines, Washington, D. C.

Metal Radiography..................................W. E. RUDER
Research Metallurgist, General Electric Company, Schenectady, N. Y.

Discussion.......................................H. S. RAWDON
Bureau of Standards, Washington, D. C.

Magnetic Analysis of Steel...........................R. L. SANFORD
Physicist, Bureau of Standards, Washington, D. C.

Discussion.......................................HENRY M. HOWE
Professor Emeritus of Metallurgy, Columbia University, New York.

AFTERNOON SESSION, 2.00 P. M.

Electrically Driven Reversing Rolling Mills...............WILFRED SYKES
Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.

Discussion.................................DAVID B. RUSHMORE
General Electric Company, Schenectady, N. Y.

Discussion.......................................J. ELIAS FRIES
Chief Electrical Engineer, Tennessee Coal, Iron and Railroad Company, Birmingham, Alabama.

Discussion.....................................ROBERT HOBSON
President, Steel Company of Canada, Hamilton, Ontario.

Discussion.....................................ADDISON H. BEALE
General Superintendent, Mark Plant, Steel and Tube Company of America, Indiana Harbor, Indiana.

The Open-Hearth Furnace and Processes................HENRY M. HOWE
Professor Emeritus of Metallurgy, Columbia University, New York.

Temperature Measurements in Steel Furnaces.........GEORGE K. BURGESS
Chief, Division of Metallurgy, Bureau of Standards, Washington, D. C.

The Manufacture of Ingots for Locomotive Tires and Rolled Wheels
LAWFORD H. FRY
Standard Steel Works Company, Burnham, Pa.

Discussion.................................GUILLIAEM AERTSEN
Assistant to Vice-President, Midvale Steel and Ordnance Company, Nicetown, Pa.

EVENING SESSION, 7.00 P. M.

SEMI-ANNUAL DINNER

Impromptu Remarks in Response to Call of the President.

ADDRESS OF THE PRESIDENT

ELBERT H. GARY
Chairman, United States Steel Corporation, New York

GENTLEMEN: Of course I recognize that you have been applauding a principle which pertains to the very life of progressive industry. And yet I would like to have you always remember that I fully appreciate your personal kindness to me.

I have had little time to prepare an address. In fact, it is with some hesitation that I will discuss briefly some of the questions which are particularly in our minds at the present time. I concluded you would not be satisfied if I did not do so.

The attention of the members of the American Iron and Steel Institute has of late been focussed on the attempt of leaders in the American Federation of Labor to unionize the iron and steel industry of this country.

The present campaign was started at St. Paul, Minnesota, June 13, 1918, by the adoption of a resolution introduced by delegate W. Z. Foster, couched in the following language:

> "WHEREAS, The organization of the vast armies of wage-earners employed in the steel industries is vitally necessary to the further spread of industrial democracy in America; and
>
> "WHEREAS, Organized labor can accomplish this great task only by putting forth a tremendous effort; therefore, be it
>
> "*Resolved,* That the executive officers of the American Federation of Labor stand instructed to call a conference, during this convention, of delegates of all international unions whose interests are involved in the steel industries, and of all the State Federations and City Central bodies in the steel districts, for the purpose of uniting all these organizations into one mighty drive to organize the steel plants of America."

The movement appears to have proceeded, under the general direction of Foster, without much result, until June 13, 1919, when another resolution was adopted by the American Federation of Labor at a meeting held in Atlantic City, which reads as follows:

> "WHEREAS, Every labor union in America, regardless of its trade or industry, has a direct and positive interest in the organization of the workers in the iron and steel industry, because the accomplishment of this vital task will greatly weaken the opposition of employers everywhere to the extension of trade unionism and the establishment of decent conditions of work and wages; and
>
> "WHEREAS, The organizing force now in the field working upon this vast project is altogether inadequate in strength to carry on the work in the vigorous manner imperatively demanded by the situation; therefore, be it
>
> "*Resolved*, That President Gompers of the American Federation of Labor, and Chairman of the National Committee for Organizing Iron and Steel Workers, be authorized to call a conference, during the convention of the American Federation of Labor, of the heads of all international unions affiliated with the A. F. of L., to the end that they make arrangements to lend their assistance to the organization of the iron and steel industry."

President Gompers thereupon named the heads of twenty-four affiliated organizations to act as a committee to develop and carry out plans for unionizing the iron and steel industry pursuant to the resolutions mentioned. You are familiar with what has occurred since that time and you are more or less acquainted with the history of the different union leaders who have been connected with the attempt to enlist the employees and to bring about a strike in the manufacturing works.

The strike, which has been directed by the union labor leaders and was begun, so far as I am informed, without any request or authorization from the workmen themselves, has been conducted in the usual way. Immediately preceding the day fixed for ordering out

the men, intimidating letters, large numbers of them being anonymous, were sent to the families of the workmen threatening physical injury to the father or husband, damage to or destruction of the home and kidnapping of the children unless the employee referred to should obey the order to strike. A number of the workmen, who had joined the unions voluntarily, accepted the order to strike, and others remained away from the factories through fear. In many, if not most of the mills, the larger number of employees continued to work without interruption. At the beginning many of the workmen who attempted to continue their work, and others who had remained at home through fear and attempted to return, were confronted in the public streets and elsewhere by strikers, or pickets, and importuned to participate in the strike; and many were assaulted and seriously injured. After protection was afforded by the police, sheriffs' deputies, state constabulary and, in some cases, state or national troops, the numbers resuming work increased appreciably from day to day until in many places operations are about normal. Taken as a whole, the situation at present is good and steadily improving.

It will be observed that the strike is not the result of any claim by any workmen for higher wages or better treatment nor for any reason except the desire and effort on the part of union labor leaders to unionize the iron and steel industry. As stated in the first resolution, the action taken was "for the purpose of uniting all these organizations into one mighty drive to organize the steel plants of America."

Without discussing for the present the merit or demerit of labor unions, it may be observed that union labor leaders openly state that they seek to unionize or, as they say, "organize" the whole industry of this country. Those who do not contract or deal with unions, although they do not combat them, insist upon absolute freedom to both employer and employee in regard to

employment and the management of the shops. The non-union employees and their employers both stand for the open shop. The unions argue for the closed shop or, as the leaders now term it, "the right of collective bargaining through labor union leaders."

Every proposition contended for by the labor union leaders at the National Industrial Conference at Washington would irresistibly lead to domination of the shops and of the men by the union labor leaders. Every position taken by the other side centered on the open shop. This is the great question confronting the American people and, in fact, the world public. From 80 per cent. to 90 per cent. or more of labor in this country is non-union. It is for them and the employers generally and the large class of men and women who are not, strictly speaking, employers or wage-earners, to determine whether or not it is best for the whole community to have industry totally organized. Judging by experience, we believe it is for the best interest of employer and employee and the general public to have a business conducted on the basis of what we term the "open shop," thus permitting any man to engage in any line of employment, or any employer to secure the services of any workman on terms agreed upon between the two, whether the workman is or is not connected with a labor union. The verdict of the people at large will finally decide this matter, and the decision will be right.

The fundamental question really submitted to the Conference for recommendation to industries was the open shop; it could not be decided by majority vote of the delegates for the reason that the Conference was organized into three groups called Labor, Employers and Public. No affirmative action under the constitution or adopted rules could be taken except by the unanimous vote of the three groups, each of which voted by a majority of all its members. It was necessary to have such a condition, as otherwise there could be no "conference" in which there would be an agreement between capital and labor, so-called.

The union labor advocates stand for collective bargaining through the unions. The others favor collective bargaining through representatives selected by the employees themselves from their own numbers.

The Employers Group offered the following resolution:

> "*Resolved,* That, without in any way limiting the right of a wage-earner to refrain from joining any association or to deal directly with his employer as he chooses, the right of wage-earners in private as distinguished from Government employment to organize in trade and labor unions, in shop industrial councils, or other lawful form of association, to bargain collectively, to be represented by representatives of their own choosing in negotiations and adjustments with employers in respect to wages, hours of labor, and other conditions of employment, is recognized; and the right of the employer to deal or not to deal with men or groups of men who are not his employees and chosen by and from among them is recognized; and no denial is intended of the right of an employer and his workers voluntarily to agree upon the form of their representative relations."

The Employers Group voted in favor of this resolution. The Public Group and the Union Labor Group voted against it.

The Public Group offered the following resolution:

> "The right of wage-earners in trade and labor unions to bargain collectively, to be represented by representatives of their own choosing in negotiations and adjustments with employers in respect to wages, hours of labor and relations and conditions of employment, is recognized. This must not be understood as limiting the right of any wage-earner to refrain from joining any organization or to deal directly with his employer if he so chooses."

The Public Group voted in favor of this resolution. The Employers Group and the Union Labor Group voted against it.

The Union Labor Group, after presenting and advo-

cating different forms of resolutions, finally offered the following:

> "The right of wage-earners to organize without discrimination, to bargain collectively, to be represented by representatives of their own choosing in negotiations and adjustments with employers in respect to wages, hours of labor, and relations and conditions of employment is recognized."

But, as shown in discussions, this was intended to be only another form of the paragraph on this subject in the original resolution offered by the Union Labor Group, which reads as follows:

> "The right of wage-earners to bargain collectively through trade and labor unions with employers regarding wages, hours of labor, and relations and conditions of employment."

It was stated by Mr. Fish of the Employers Group that "we cannot read this resolution without reference to the history of the last two weeks, and the events of yesterday. . . . As the argument in this Conference has developed, it has been perfectly clear that the sum and substance of the resolutions with reference to collective bargaining that have been presented heretofore, excepting the substitute from the Employers Group, the Chadbourne Resolution and the substitute offered for it by the Employers Group, that these resolutions in substance meant this and nothing else, that this Conference is asked to take action which will force, if possible, the hundreds of thousands of employers in industries throughout this country to recognize the labor unions whether they will or will not, and to force their organizations to deal with the labor unions against their will. . . . I shall personally feel obliged to oppose this resolution unless there is a plain definition as to what is meant by bargaining collectively."

The Union Labor Group and the Public Group voted in favor of the resolution. The Employers Group voted against it. Thereupon the Union Labor Group retired from the Conference.

All through the Conference, whenever the question of collective bargaining was discussed, it was apparent that the union labor leaders would not support any resolution in favor of collective bargaining, except on the basis that collective bargaining meant bargaining through labor unions. For instance, on Tuesday when the first two resolutions above quoted were under discussion and ready for vote, Mr. Chadbourne for the Public Group spoke as follows:

> "Mr. Chairman, I want to make a statement and to ask a question or two of Mr. Gompers with the Chairman's permission." (Turning to Mr. Gompers.) "Mr. Gompers, the Public Group will retire and reconsider its vote, with the recommendation of its chairman, Mr. Baruch, if you and your group will do either one of two things: either add, 'or other organizations' after 'labor and trade unions' in the resolution, or give it as your group's interpretation upon this record equally as solemn as the vote that is taken upon the resolution, that it is the interpretation of the gentlemen in your group that it does mean any other organization or any other association."

To this the Union Labor Group would make no response.

As further evidence of the attitude of the union labor leaders it may be mentioned that in the twelve demands published by the leaders who were conducting the strike they included and insisted upon the following:

"Abolition of company unions."

The labor unions claim that collective bargaining through different forms of shop organization made up of the employees tends to limit the extension of unions; while the non-union employees and their employers insist that collective bargaining through labor unions means that employees are forced to join the unions, as otherwise they could not be represented. So it is perfectly clear that the whole argument returns to the main proposition of open or closed shop.

In the Conference there was no objection offered by

anyone to some form of collective bargaining as between employees and employers, provided both were free from "outside" representation and direction.

The Labor Group, so-called, was made up of union labor leaders, leaving unorganized labor without special representation. The same mistake seems to have been made by a large portion of the public which was made throughout the war, namely, that organized labor really represents the workmen or wage-earners generally, notwithstanding, as a matter of fact, at least 85 per cent. of the total are non-union—not members of any union organization. The Employers Group, in which were men first class in every respect, included men connected with large and important lines of industry, and also included several others, some of whom at least should have been with the Labor Group. In selecting the Public Group there were overlooked thousands of vocations, professions, artisans and other lines of industry, all of whom are more or less affected by the cost of production, the expense of living and, therefore, the control and conditions of both labor and capital.

However, it would seem there were many objects which might appropriately have been considered by the Conference and conclusions for recommendations arrived at by unanimous consent which would be advantageous to the public good and, therefore, to all mankind, such as working hours, living and working conditions, women's work, child labor, recreation, medical and surgical treatment, pensions, relief in times of stress, rates of compensation, schools, churches and other educational facilities. With the right disposition and intelligence the Public Group, sole survivor of the Conference, can agree upon recommendations to the industrial world which should be of substantial benefit. All of us are in favor of these principles and of any others that may be suggested which we believe will be of real benefit to the wage-earners and to the general public.

I conceive it to be proper in this family of industrial

workers consisting of 2000 members of the most important basic industry, to claim that we have demonstrated in practice we are upon a plane which is higher and better than ever before occupied by this industry in this country; that we have been striving to deserve the approval of all who are interested in our business and our decisions; that we have sought the confidence of our employees, our customers, our competitors, our principals, who own the properties we manage, and the general public.

And yet it would be unfortunate if we could not discover opportunities for further improvement; if we failed to read or to listen to the criticisms of others; if we let pass the requests or suggestions of our workmen for changes which they believe would be proper concerning their employment; if we neglected to give our employees, individually or in groups, opportunities to discuss with the managers all questions of mutual interest; if we minimize in any degree the well recognized fact that the public good is of prime importance and that private interests must be subordinated. It is a pleasure to me to know from long experience that I am appealing to a sympathetic audience in behalf of a continued effort on our part to be more worthy of the respect and confidence of every right-thinking person who is familiar with our industrial life.

Considerable has been said in public of late concerning the attempt to spread the doctrine of bolshevism in this country. All of us have known for some time that this disease is persistent and that there has been some inoculation even in this best of countries. Still we deny that there is danger of serious trouble. There is only one way to treat this disease and that is to stamp it out, to meet it boldly wherever it can be found, to expose it and give it no chance for development. In this free country, with its reasonable laws wisely administered, its golden harvests, healthful climate, peace-loving inhabitants who are generous in contributions for relief and protection, schools, churches and hospitals, there is no room except in the prisons for the anarchist, the bolshevist or other

individual who seeks to substitute the rule of force for the rule of law and reason. If there are slinking, desperate, murderous bolsheviki in this country, even in small numbers, I believe the Secret Service Department of the Government should detect and expose them and that the iron hand of justice should punish them as they deserve, and as I have faith in this country and in its institutions, I believe this will be done and done promptly. Any one who doubts the ability of the proper authorities to protect the persons and property of our people against bolshevism and other similar doctrines, fails to appreciate the courage of our citizens and the terrible force and strength of their subdued calmness when surrounded by threatened danger.

For ourselves, let us be fair and just, considerate and determined, hopeful and complacent. We shall emerge from the waves of unrest which naturally follow the demoralization and terrors of war, and as a people will be better and stronger than ever.

Mr. Willis L. King: With your approval, Judge Gary, and the permission of the members of the Institute, I would like to take the floor for a moment. Mr. Butler has a resolution to present which I would like you to hear.

Mr. Joseph G. Butler, Jr.: Judge Gary, and my other beloved brothers of the American Iron and Steel Institute:

The American Iron and Steel Institute owes a debt to Judge Gary. (Applause.)

It owes a debt to itself. It owes a debt to the entire iron and steel industry of the United States. I think I may go further in saying it owes a debt to the country. Possibly I may go still further and say that it owes a debt to the entire world. I am going to give you an opportunity to discharge that indebtedness.

I have prepared a short resolution, and with your permission I will read it:

WHEREAS: Elbert H. Gary, President of the American Iron and Steel Institute, has rendered to the American people and to the American iron and steel industries a service of inestimable value by his course as a representative of the public in the Industrial Conference at Washington; therefore

BE IT RESOLVED, That the American Iron and Steel Institute, assembled in its semi-annual meeting, hereby records its unqualified approval of Mr. Gary's firm stand against any infringement of the rights of the individual in labor or in business, rights fundamental to American industrial supremacy as well as to American liberty; that it admires the vision and courage enabling him to discern and effectively oppose the radicalism injected into trade unionism by unscrupulous leaders, an element especially dangerous under present conditions, when worldwide unrest has created an opportunity for agitation aimed at the perpetuity of institutions under which our country has achieved its strength and our industries attained their efficiency and prosperity.

MR. KING: I would like to ask whether everyone in the room, particularly in the back part of the room, heard Mr. Butler? (Cries of yes, yes, yes.)

MR. KING: Is that motion seconded?

The motion was seconded by Mr. E. A. S. Clarke and many others.

MR. KING: Is there any discussion? Does anyone choose to speak? (Cries of question, question, question.)

MR. KING: If you are all ready for a vote, those who favor that resolution will please say aye; contrary, no.

The resolution was unanimously carried amidst great applause and cheers, the assembled gentlemen rising.

JUDGE GARY: Gentlemen, I thank you. I would be less than fair and less than sincere if in this connection I failed to emphasize the thought that while circumstances have happened to place me in a position which has centered

your thoughts and your words of approval upon me, yet there is not much strength in anyone who happens to be prominently connected with or the leader of a movement unless he has the necessary support. And therefore I want to share the very generous confidence which you have expressed in words with large numbers of others.

I would like to say that from the outset the positions which have been taken by your President, as expressed in words, have been without exception approved by the Finance Committee of the United States Steel Corporation, by its Board of Directors, by its stockholders as stated in many letters and telegrams which have been received, by the Board of Directors of this splendid institution, of which we are all proud, by the iron and steel industry generally of the United States and Canada, by thousands upon thousands of individuals, chambers of commerce, associations and organizations, including farmers' institutions, scattered all over this country, from north to south and east to west; and I am glad to say by the intelligent, influential, splendid press of this country.

And so you and I, all of us, cheerfully, emphatically extend the sentiments of the resolution which has been passed to all these groups of individuals to whom I have referred.

We shall now have the pleasure of listening to a discussion of the work of the Bureau of Mines by Mr. Van H. Manning, Director, Bureau of Mines, Washington, D. C.

Gentlemen, may we have absolute silence? This is a small room, compared with the number of people. It has been very much crowded this morning. It was perfectly natural that some of you should like to get a little fresh air; but I hope that even if some of you do deem it proper to leave the room temporarily you will do it without making any noise whatever, and refrain entirely from speaking while you are in the room.

Also I should like to call your attention to the fact that on various previous occasions it has been suggested by some particular members that, where the ventilation is

not adequate for a large crowd, smoking is somewhat injurious to the lungs of some of our members; so I am making bold to now request what has been suggested and decided by you on other occasions, that you please refrain from smoking while you are in the room. (Cheers and applause.) Those who are cheering do not smoke. (Laughter.) If it is necessary, if you deem it to be necessary to have just another whiff or two before you put aside you cigar, and you will suggest it, we will suspend proceedings for five minutes to give you that opportunity. Now you see it is up to you. I am not ruling with an iron hand nor a wooden mallet. But I am putting into expression what has been in the thoughts of a number.

Now will you kindly give your very close attention to an interesting paper by Mr. Manning?

Mr. Van H. Manning: Mr. Chairman and gentlemen: I consider it a very high honor indeed to be offered the privilege of appearing before this assembly, a great privilege indeed to have followed your distinguished president in a splendid exposition of what happened in Washington. I attended some of those meetings and saw the action of the conferees and various committees; but I have no comments to make, gentlemen, I am a Government official and I have been taught a lesson recently that it is best for an official in my position not to say very much regarding industrial conditions in the country today.

I am going to present to you a subject that I know that you are not half as interested in as the discussion which your Chairman has just made, and that is the work of the Bureau of Mines. I cannot go into the full details because the ramifications of the work of the Bureau of Mines is very great and getting greater every day. For example, last night at ten o'clock the Chief Engineers of the City of New York and of New Jersey came to see me at the hotel and asked whether or not the Bureau would undertake to determine how much carbon monoxide could be saved in the proposed tunnel from here over to Jersey. That involves considerable expense and considerable time.

It is problems of that character, and others, that the Bureau has to confront from time to time. I am going to give you today just a short resumé of some of the work, which I hope will be of interest to you.

Mr. Manning then presented the paper entitled "The Work of the Bureau of Mines."[1]

THE WORK OF THE BUREAU OF MINES

Van H. Manning
Director, Bureau of Mines, Washington, D. C.

It is unquestionably true that the most desirable end-point of progress can never be attained if development is allowed to be governed only by convenience and immediate results. The viewpoint of the Bureau of Mines is to look beyond the immediate necessities to the final goal to be attained, and it is my purpose that the Bureau investigators shall keep this in mind in the progress of their work. It is true that in the first development of scientific control, that general conditions must first be established; when this has been accomplished the work must not be allowed to rest there, but must be carried on with a due appreciation of individual demands and the changing needs that progress in other lines brings about. Industrial co-operation with governmental agencies is highly desirable, and absolutism of control over the results of industrial research is to be deplored.

The Government of the United States, through its research laboratories should supplement the work of industry. Secretary Lane, in commenting to me upon the proposed organization of the Division of Research and Statistics of the American Petroleum Institute, says: "It is quite manifest that private enterprise must stand in the forefront in the development of this industry, and that what the government can do will be supplemental and suggestive. We are behind the rest of the world in the use of our oil for fuel purposes. We are spendthrifts in this, as in other of our national resources. Throughout the nation, we must make a drive to increase production. This is a slogan of this time, but that does not mean we should make a drive to exhaust the resources which God alone can duplicate."

"I think that Congress can be largely helped by the sane presentation of wise policies touching this industry. Congress has difficulty often in getting the large view of practical men who speak without personal interest, and such an institute could speak, not for the individual, but for the industry, and show how it might be best developed in the interest of the country. To do these things and do them adequately would require the men in the industry to take the attitude of statesmen, and not of selfish exploiters; it means that they must tax themselves liberally and generously; it means they must think of themselves as trustees for a public as wide as the world."

What Secretary Lane says concerning the oil industry may well be said of the iron and steel industry, or any branch of the business of mining and metallurgy, from the raw material to the fabricated article.

Next year will be the tenth anniversary of the founding of the Bureau of Mines, and I would like therefore, to counsel with you briefly as to whether, in the decade now almost elapsed, the Bureau has met the conditions I have just outlined, in its record of work done.

Founded at a time when conservation of national resources was to the forefront of the mind of the nation, the basal idea of the Bureau of Mines was the prevention of loss of life and health in the mining industry, and the prevention of waste of natural resources, through uneconomical methods of either mining or metallurgical treatment, only removing a part of the treasures of Nature from their deposits underground, or else only recovering a part of them in the subsequent treatment or use of the mineral.

The work which the Bureau engineers have done in rendering immediate assistance in the case of mine explosions or fires to prevent loss of life or of mineral wealth has naturally attracted much attention, and the warm letters of commendation received from mine operators, praising the courage, skill, and resourcefulness of Bureau men who, by prompt action, have saved the lives

of entombed miners or prevented the loss of valuable mineral resources, are a gratifying indication of the value of this work. I should mention in this connection that our engineers have developed a type of breathing apparatus, to permit the entering of mines filled with gas and smoke following an explosion or fire, that is far superior to any European type of apparatus, and greatly adds to the safety and convenience of the wearer. The ten mine

Fig. 1.—Bureau of Mines Rescue Station at Seattle, Wash.

rescue cars and eight mine rescue stations of the Bureau are so distributed that they are able to make response to a call for assistance with a minimum of delay and the ordinary occupation of their personnel is to train the mining employees of the district in the use of mine rescue apparatus and in the rendering of first aid to their fellow employees. This has a triple benefit; it trains the men on the spot to render immediate aid in the event of a disaster or accident, it turns the minds of the men toward the necessity for the prevention of disasters, and it brings out the co-operation of the companies and the men in the work of conservation of life, health and natural wealth. Like Providence, the Bureau finds it most desirable to

help those who are making an effort to help themselves.

Even more important, in my opinion, is the less spectacular work that has been done to prevent the occurrence of mine disasters. The use of unsafe explosives was responsible for much loss of life and I am glad to be able to say that the work which the Bureau has done in the testing of explosives and furthering the development of safe types has not only gained it an international reputation for its achievements in this line, but has also led to a very notable decrease in fatalities from explosives. The chart

Fig. 2.—Mine rescue truck of the Bureau of Mines.

for the past decade would show the line for fatalities due to explosives going steadily downward, while the line for the use of safe explosives inclines steadily upward. The investigations at the Pittsburgh Station and the experimental mine at Bruceton, Pa., of mine gases and the causes of mine explosions have been most helpful, and if this work had had no other result than the development of the use of rock dust barriers to prevent the propagation of explosions it would have paid for itself. The study of the explosibility of coal dust is still in progress, and the limits of its value cannot yet be seen. In safeguarding the life of the miner from the mechanical stand-

point, I must mention the development of safe forms of underground illumination, so important in preventing accidents, as well as in lessening the explosion and the fire hazard, and of safe electrical equipment for use in gaseous mines.

The study of underground conditions, as affecting the health of the miner, in which we have had the co-operation of the Public Health Service, has been productive of excellent results, and a study made of the Joplin district, Missouri, has led to great improvements. Work is still in progress in other parts of the West and the indications are that these studies will not only bring about better

Fig. 3.—Mine rescue car of the Bureau of Mines.

hygienic conditions underground, but also greatly increase the productive capacity of the miner in many instances.

Turning now to the wise use of our mineral resources, and confining myself to specific instances, let me cite the study of the use of fuel under marine boilers, made by the Bureau at the request of the Emergency Fleet Corporation, in which it was found that by properly modifying the design of the boiler six tons of fuel would be enabled to do the work of seven. This has led to study of the use of fuel in the refining of petroleum, in which it is found even greater savings can be made. I wish you particularly to note that these were co-operative in-

vestigations; an industry which had a problem asked for help, the Bureau lent its resources and the industry paid the bills, with the result that both the industry and the nation was the gainer. I must not forget to mention the extremely valuable studies on the transmission of heat that have been made in connection with our work on the utilization of coal, and which are only just beginning to attract the attention their importance and usefulness deserve.

Fig. 4.—Mine rescue crew of the Bureau of Mines, equipped with rescue apparatus, entering a mine.

In the important field of petroleum technology co-operative work with the Indian Office in Oklahoma has made it possible through a yearly expenditure of $17,500 to shut off water in wells and increase the production by a value of $2,500,000 per year. As a result the operators in the Wyoming field have voluntarily contributed $30,000 to be expended under the direction of the Bureau for the conservation of oil and gas on their properties, and the State of Oklahoma has made $25,000 available for similar work. The loss of oil and gas by fire during the past

decade has been enormous, in one week in 1914 the loss in the Cushing and Healdton fields alone amounted to over a million dollars. The Bureau has been able to point out that most of the more disastrous fires resulted from carelessness or improper storage and transportation facilities, and that by better methods of combating fires they could be more easily controlled. Through the adoption

Fig. 5.—View of a large oil tank, which was struck by lightning and is burning.

of these recommendations enormous quantities of oil and gas have been conserved for use. Gasoline is a necessity of modern life and the studies of Bureau engineers have greatly increased the proportion of gasoline which may be recovered from natural gas. A study of the Government specifications for motor gasoline has disclosed that it was too rigid and was restricting the output of gasoline, since it had been adopted as a model for state and munic-

ipal requirements. Oil shales, sooner or later, will become an important source of mineral oils, but the problem of their utilization is still far from solution. I believe that now is the time to begin to devise commercial methods of obtaining oil from shale, instead of waiting until stern necessity forces our hand, and the Bureau engineers are as actively engaged on the problem as the funds so far available have permitted. The Internal Revenue Bureau of the Treasury Department, in trying to arrive at a fair method of taxing the petroleum industry, called upon the Bureau of Mines for help and our engineers developed a new method for estimating the future and ultimate production of oil properties that is being used as the basis of assessing the taxes imposed by Congress.

In the field of metal mining I can no more than mention the Bureau's work on the problem of smelter smoke, the treatment of low grade and complex ores of lead, zinc, and silver, the recovery of copper from oxidized copper ores, the flotation process, the recovery of the rare metals from their ores and the production of rare metal alloys, while in the non-metallic field the work looking toward the substitution of American clays for imported material, in which notable progress has been made, and also that on labor saving in the quarrying industry, which though not much in the public eye, nevertheless bulks large in the annual production of mineral wealth. I mention these few out of many lines of work as an indication of the breadth of the field and the character of the work being done in it.

Coming now to the Bureau's work in connection with the iron and steel industry, I must say at once that, in proportion to the industry's importance, relatively little has been done. Iron ore and pig iron represent one-quarter of the value of the total yearly production of mineral wealth in the United States, but of the published researches of the Bureau less than a tenth deal directly with problems in the iron and steel industry, and only about one-fifth with subjects that are at all closely re-

lated and would aid in the solution of those problems. Having already indicated that much of the Bureau's best work has been done in co-operation with industry, I do not expect you to ask me why this is so, but leave the answer to this question to you. The work of the Bureau on safety and health conditions around blast furnaces and steel plants is doubtless well known to you. Broadly speaking, the organic act establishing the Bureau defines its work as (1) looking after the safety and health of the miner, and (2) the prevention of mineral waste. Inasmuch as its work is so defined, it can be readily understood that, as the work expanded, the selection of a problem was practically altogether governed by whether or not it had to do with one or the other phases of the Bureau's work. Thus, when the time came to consider the problems connected with the iron and steel industry, it was the safety side of the subject that first received attention. Consequently, the first bulletins issued by the Bureau relating to the iron and steel industry had to do with safety in connection with blast furnace practice, around steel plants, etc. In 1915, a bill passed by Congress authorized the establishment of ten mining experiment stations of the Bureau in addition to those which had already been established. The first three were established in 1916, all of them in non-ferrous mining districts. Of the second three which were established, one was located in the Northwest, and to it was assigned the problem of the beneficiation of low-grade iron ores. As is well known to all of you here, it has been estimated that the iron ore reserves of the country will last about thirty years at the present rate of consumption. However, this estimate is based upon the utilization of those ores which at the present time can be treated profitably in blast furnaces. Likewise, as you also know, there is a tremendous tonnage of ores throughout the United States, and especially on the Mesabi range which are too low-grade to permit of their being treated in a blast furnace without having undergone some form of beneficiation. The sta-

tion of which I speak was placed at Minneapolis because at this point is also the State University, in connection with which there is a State mining experiment station, and inasmuch as it is the policy of the Bureau to attack, if possible, the problems of a State through or in co-operation with a State institution, the station was built on the campus of the University of Minnesota.

By the time the station had been started at Minneapolis, the participation of the United States in the World War had come about, and as the Bureau was endeavoring to assist in the solution of problems connected with

Fig. 6.—New buildings of the Bureau of Mines at Pittsburgh, Pa. (Front).

war work, the station at Minneapolis did not at once take up the work for which it was established, but turned its attention rather to the problem of the production of manganese alloys which might be used in place of the high-grade ferro-manganese formerly produced from imported ores. The station continued to give its entire attention to this work until the signing of the armistice.

In the meanwhile the State mining experiment station continued its work on the beneficiation of low-grade iron ores, and at the time of the signing of the armistice had made so much progress along this line, as had also private interests, that the Bureau felt that, instead of giving its attention to this subject, it could better

devote its energies to (1) a study of problems connected with the mining of iron ores, and (2) an investigation of the merits of those processes which have from time to time been suggested for the treatment of iron ores other than in the blast furnace. It is perfectly well understood that the consideration of these processes is, so to speak, taking a long shot, and that iron and steel metallurgists as a rule do not believe that it will ever be possible to develop direct reduction processes. However, the Bureau looks at the matter in this way. A pound of metal is a pound of metal, no matter whether it be iron, copper, lead, zinc, or whatever else, and as such should not be wasted if it is possible to prevent. Inasmuch as one of the main functions of the Bureau is to prevent waste, it should carefully inquire into the merits of every process whose originator claims for it the treatment of ores of lower grade than are being treated by present day metallurgical processes. Although processes may be devised for bringing up the iron content of an iron ore to a point where it can be successfully treated in a blast furnace, there will, nevertheless, still remain large quantities of ores which even after beneficiation will not be suitable for blast furnace treatment, and consequently, it would greatly add to the iron ore reserves of this country if some process other than the blast furnace process could be devised for the treatment of these ores locally for the recovery of their iron content. The Bureau has only made a beginning along this line but trusts that the appropriations which are granted by Congress for its work will in the near future enable it to give this problem the attention it needs.

In addition to the field of work I have just outlined, the Bureau is, of course, also interested in all those problems which are confronting the iron and steel industry in connection with present day metallurgical practice. For example: As is well known, the so-called Bessemer ores have been largely depleted and the problem has arisen as to how it may be possible to convert non-

Bessemer ores into Bessemer ores. Considerable progress has recently been made along this line by certain commercial concerns. However, the Bureau is interested in this problem and is endeavoring to contribute its part to its solution.

Another problem is that of overcoming the ill effects of sulphur when high-sulphur coals are used in steel-making. The supply of low-sulphur coals is running low and the steel industry at the present time finds it neces-

Fig. 7.—New buildings of the Bureau of Mines at Pittsburgh, Pa. (Rear view).

sary to use high-sulphur coals. Therefore, the problem presents itself of removing this sulphur from the coal or else adding to the steel, after it is produced, some element which will neutralize the effects of the sulphur and at the same time in no way decrease the essential properties of the steel. The Bureau is fully cognizant of the importance of both of these problems and will gladly take up more extensive work on them if its funds permit it to do so.

There is also the problem of the alloy steels; that is,

of the production of steels having peculiar properties by reason of the addition of rare elements. The Bureau in connection with this work on rare metals has made an extensive study of the mining, treatment and utilization of these rare metals. This is a most promising field and it is to be hoped that in the near future it may be able to detail a sufficiently large number of investigators to this work to insure the securing of such additional data to that already possessed by the steel industry as should be available at the present time as to the influence of these rare elements on the properties of steel.

Because of the limited appropriations of the Bureau, I realize that it can do no more than assist wherever possible on the problems confronting the iron and steel industry. In other words, it can only hope to co-operate in the work which is being carried on by the industry itself and by the various technical societies.

As you know, there was a time when each company or corporation endeavored to keep to itself all information gained in connection with investigation. Now it is my impression that a spirit of co-operation has sprung up in the industry which cannot help but be very beneficial in the solving of the problems confronting the industry.

The bureau is co-operating, so far as its finances will permit, with the industry and in turn asks your co-operation in the solution of those problems which it may attack. Moreover, it will be only too glad to receive from the industry at any and all times suggestions as to the problems which should be taken up by it and which will benefit the industry as a whole. Referring again to the Division of Research of the American Petroleum Institute, which I mentioned in the beginning, let me say that in response to my suggestion that the petroleum industry would find it well worth while to assess itself 1-25 of 1 per cent. of the value of its output to be devoted to research, or approximately a million dollars a year, a reply was made that it would be better to provide three times that sum.

If the steel industry were to provide 1-25 of 1 per cent. of the value of its product for research for the benefit of the whole industry, work could be undertaken on a scale and with a degree of thoroughness that would be of incalculable benefit. I commend the plans of the American Petroleum Institute to your earnest consideration.

The industries should encourage technical and vocational training as well as research, because if this training precedes the trade training, it makes for efficiency and economy. This education can be obtained in one way; through the establishment of a limited number of fellowships by the industries at our universities and colleges for the benefit of those who show some ability to be educated as understudies in a particular line of work in which they could be employed. Unfortunately, many faithful employees are not financially able to give their children the particular education or the technical or trade experience which is desired in the business to which their parents have given the best part of their lives.

Another definite and concrete proposition has been submitted by Secretary Lane in his Americanization plan. In the mining and metallurgical plants there are many nationalities of foreign-born or foreign-speaking employees who are engaged in various lines of activities. They can neither read nor write the English language, and are, therefore, unable to understand the instructions or regulations which are prescribed by the employer, many of which are for the safeguarding of life and property.

I call your attention and endorse as strongly as I can Senate Bill 5464, by Mr. Smith of Georgia, "to promote the education of native illiterates, of persons unable to understand and use the English language, and of other resident persons of foreign birth; to provide for cooperation with the States in the education of such persons in the English language, the fundamental principles of government and citizenship, the elements of knowledge pertaining to self-support and home making, and in such other work as will assist in preparing such illiterates and

foreign-born persons for successful living and intelligent American citizenship."

The most recent statistics show 620,000 foreign-born miners in this country, and about 75 per cent. of these miners are non-English speaking foreigners. The best estimates from a number of the larger mining states are to the effect that the non-English speaking foreigners suffer twice the fatalities that the English-speaking miners do. As an average state compensation is $3,000, which is a fair figure, the total economic loss each year to the country through the excess of deaths of non-English speaking miners alone amounts to $2,790,000. On the same basis it is estimated that the excess of non-English speaking miners injured each year amounts to 69,750 men. This is a loss in wages alone of $1,743,750, or a total for deaths and injuries of $4,533,750. This is entirely aside from the other costs to the industry in production lost.

There are certain radical elements whose gospel is violence, which have interfered with production when this country was in dire need of their services. The leaders, possessing an intelligence of cunning, have preyed upon the ignorance of other men. My plea, therefore, is that co-operative effort on the part of the Government, States, and industries will not only save human life and suffering in the allied industries, but would also be of great economic benefit, and will make loyal American citizens out of men who through their ignorance remain aliens.

President Gary: Gentlemen, I next introduce Mr. W. E. Ruder, Research Metallurgist, General Electric Company, Schenectady, N. Y.

Mr. Ruder: Judge Gary and gentlemen: I will read this paper only in abstract in order to save your time. The subject of metallurgical radiography has awakened considerable interest recently, particularly in England. It was thought best to draw attention to the work which has been done in this country; and to emphasize certain points which seem to have been previously lost sight of in the discussion and in the presentation of papers.

METAL RADIOGRAPHY

W. E. Ruder
Research Metallurgist, General Electric Co., Schenectady, New York.

The remarkable property of X-rays, by means of which one is able to see through otherwise opaque objects, has, from the time of their discovery, made a strong appeal to the imagination. All sorts of remarkable powers have been attributed to these rays. The results actually achieved have been truly marvelous and yet much that we have been led to believe in the past is, even today, still in the realm of the "hoped for" to those whose lives have been devoted to the study of this subject.

In presenting this paper I do not pretend to be offering anything that is essentially new or original. My sole object is to give a brief outline of the principles underlying the application of X-rays to the examination of metals and to tell what can reasonably be expected from such application under present existing conditions. If the results given are in some cases apparently contradictory, it should be borne in mind that an exact technique has not yet been worked out.

During the last decade the metallurgist has found it increasingly necessary to keep in touch with the achievements of those working in the realm of so-called pure science. The constitutional diagram, the phase rule and the thermo-chemistry of furnace reactions quickly became the instruments by which the metallurgist gauged his advances.

Since the announcement of their discovery in 1895, the study of Röntgen or X-rays has opened up the entire field of atomic physics and discloses much of the part that electricity plays in the structure of matter.

At least two distinct phases of this study are of particular interest to the metallurgist, namely, the determination of the crystal structure and the atomic arrange-

ment in crystals of metals and alloys, * and the examination of the physical condition of the ordinarily invisible portions of a metallurgical product. It is the purpose of the present paper to deal only with the second of these applications, outline its technique, possibilities and limitations.

In 1915 Dr. W. P. Davey † described his investigation of a steel casting by means of X-rays and showed that flaws of certain kinds, such as blow-holes or fair-sized slag inclusions, were readily discernible. Since that time much interest has been shown, both in this country and abroad, in the practical application of this new tool.

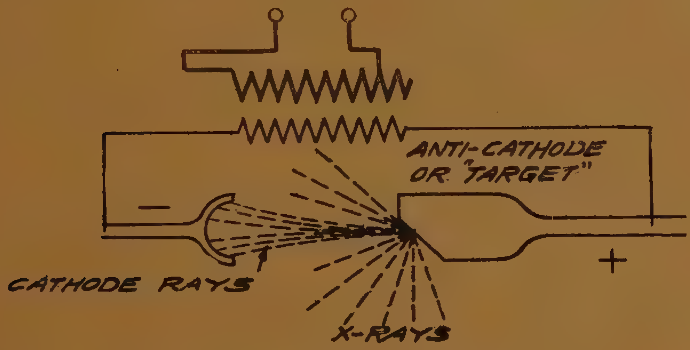


Fig. 1.—Production of X-rays.

X-rays are ether waves or vibrations of very short length ‡ (.000,000,048 to .000,000,036 mm.) produced by the impact of cathode rays upon any substance (see Fig. 1). Cathode rays are streams of negatively charged electrons given off by the cathode under the action of high voltage and under conditions most favorable to ionization. These conditions may be that of a rarified atmosphere (.006 to .001 mm. Hg.) or of a heated cathode in a very highly evacuated tube. In either case the cathode discharge is electronic. The latter, however, represents the most advanced art in X-ray tube manufacture. Each elec-

* A. W. Hull. Phys. Rev. N. S., Vol. 10, 661-696.
† G. E. Rev. 18, 25-27 134-6 (1915).
‡ Visible light rays range from .000813 to .000530 mm. in wave length.

tron in the cathode stream sets up a magnetic field perpendicular to its path, and the very rapid retardation of these electrons as they strike a substance (an X-ray target, for example) sets up electro-magnetic disturbances or other waves of short length, and consequently great penetrating power. These are called X-rays. Rays produced in this manner have the power of producing fluorescence from certain salts of the alkali and alkali-earth metals, of ionizing gases, of affecting the electric resistance of a selenium cell, of producing physiological effects in living tissue, and of affecting the photographic plate in much the same manner as visible light.

Several factors govern the effectiveness of these X-rays: first, the velocity of the impinging cathode stream which is directly dependent upon the voltage applied; second, the intensity of this stream determined as current flowing through the tube; and third, the nature of the metal in which the X-rays are produced. Waves of very short length are usually spoken of as "hard" and the longer ones as "soft." Hard rays have the greater penetration and for this reason high voltage is required when penetration is the primary consideration. In making a radiograph, however, not only is the penetration important, but the time of exposure is directly dependent upon the amount of X-rays that reach the emulsion. The intensity of radiation diminishes, as in the case of visible light rays, with the square of the distance from the point of source to the surface of the object to be radiographed.

When visible light rays fall upon a transparent body, only a certain percentage of the rays pass through. Some are absorbed and others are reflected. Just so in the case of X-rays. Part of the impinging rays are "reflected," that is, "characteristic" rays are produced, the incident rays setting up a secondary radiation characteristic of the substance upon which they fall. The second part is "absorbed" or "scattered" and so dissipated. Characteristic rays are produced only when the incident

primary rays are more penetrating than the characteristic secondary radiation and their production is analogous to the production of fluorescent light.

Scattering is produced by deflection of the rays by internal structural surfaces in matter of any kind and increases with the thickness and atomic weight of the scattering medium. It corresponds to the scattering of visible light by fog. It is, then, this scattering and production of secondary radiation that puts such narrow limits upon the use of X-rays in examining substances, particularly those of high density, such as are encountered in radio-metallography (Fig. 2).

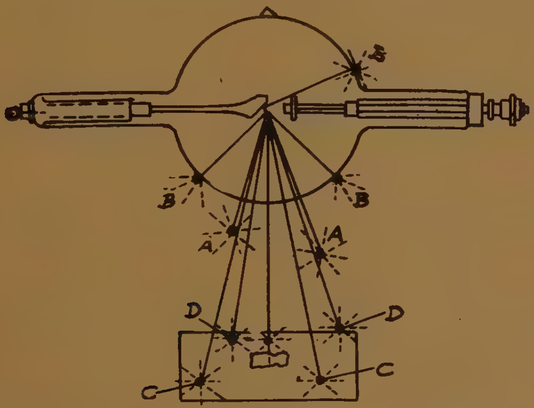


Fig. 2.—Production of secondary radiation. A—Secondary rays produced in air. B—Secondary rays produced in the bulb. C—Secondary rays produced in the object. D—Secondary rays produced on and just under surface.

The absorption of homogeneous X-radiation may be expressed by the following equation:

$I = I_o \varepsilon^{\lambda x}$

I_o = the intensity of the incident beam.

I = the intensity of the emergent beam.

ε = 2.7182

λ = coefficient of absorption of the substance.

χ = the thickness of the substance.

Except in a very general sense, this equation is of

little value in practice, because we always have to deal with radiation that is far from homogeneous.

Bearing in mind the foregoing brief survey of the underlying principles governing the application of X-rays, let us now consider their application to the study of metals.

Unfortunately, we are at present limited in examining metals by means of a fluorescent screen, such as is used by physicians, to about .01 to .02 inches thickness of metal, and obviously, internal flaws in such thicknesses would be relatively unimportant. For the examination of a manufactured article, for the inspection of assembly, the screen has been successfully used. For most purposes, however, a photographic plate must be used so that the cumulative effect of time may be utilized.

Photographic plates do not have the same sensitiveness to all wave lengths of X-rays, so that when working with very short wave lengths in work requiring a high degree of penetration, a different plate will be needed than when working with soft rays of longer wave length. For this reason only plates made for the particular purpose should be used.

The time of exposure is appreciably shortened by the use of an intensifying screen, a fluorescent surface placed close to the plate which, under the influence of X-radiation, emits visible light rays of a color which readily affects a photographic plate. In metal radiography the use of such a screen is almost a necessity, owing to the thickness and high atomic weight of most metals. Calcium tungstate, which emits a blue light under these conditions, is particularly suitable for the purpose. It must, however, be of very fine grain because this grain shows up in the negative.

Radiographs are *detail shadowgraphs* and as the rays cannot be focused as in ordinary photography, the image will always be "life size" or larger. Moreover, the rays producing the shadows are not parallel but emanate from

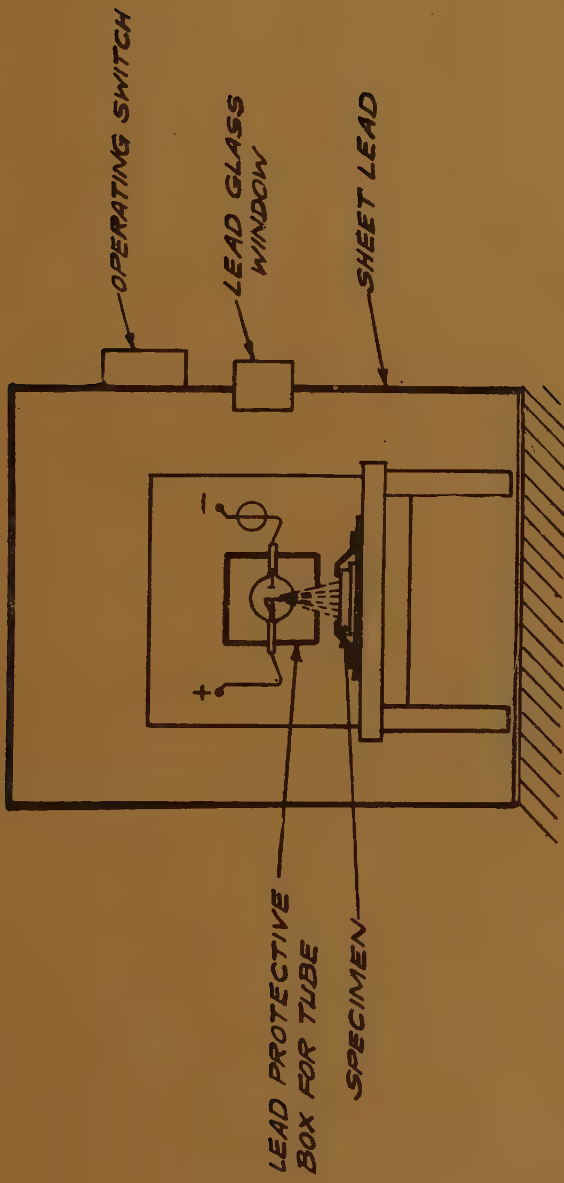


Fig. 3.—Protection of operator.

a point-source. For this reason variations in intensity caused by differences in density in the object will be sharper when near the emergent side, and their sharpness will diminish and their size apparently increase as they are nearer to the incident side. This point-source distortion is diminished by increasing the distance of the tube from the object, at the same time, however, decreasing the intensity of the rays.

As previously pointed out, X-rays impinging upon any substance, air, glass, wood, metal, etc., produce secondary rays which also have an effect upon the photographic plate. In metal radiography it becomes of primary importance to guard against this extraneous radiation by protecting the plate on all sides except in the direction in which it is desired to radiograph. This protective sheath is usually made of lead, and in examining thick sections should be at least ¼-inch thick. The aperture in the protective box surrounding the X-ray tube must be small enough to prevent the spread of the rays beyond this protective sheath.

Most important, however, is the protection of the operator from the action of both the direct and secondary rays. Owing to the high penetrating power of the rays used, protection is even more important in metal radiography than in radio therapeutics. Too great care cannot be taken to guard against these rays. Complete protection should always be provided for. An arrangement providing such protection is shown in Fig. 3.

A suitable arrangement for the making of radiographs is shown in Fig. 4. The "camera" is merely a special plate holder, light tight, of course, and carrying an intensifying screen. The object is placed on this camera directly. If the sides are not parallel, unsatisfactory results, due to unequal penetration, will result. In the case of curved surfaces, a film and flexible screen must be used.

The distance between the X-ray tube and the object is so regulated that a uniform effect may be obtained over

the whole plate. For a 5 x 7-inch plate, this distance should be at least fifteen inches.

The time of exposure is the most important consideration and has, unfortunately, been given little attention in previous publications. It is particularly desirable in investigating a new field, that all data be given. In this case, voltage, current, distance from plate to tube, time of exposure and kind of plate should be recorded.

Now it is evident that, provided the voltage is high enough to cause even a small amount of radiation to pass through the metal, a radiograph can be obtained if sufficient time is allowed. The time required is also a direct

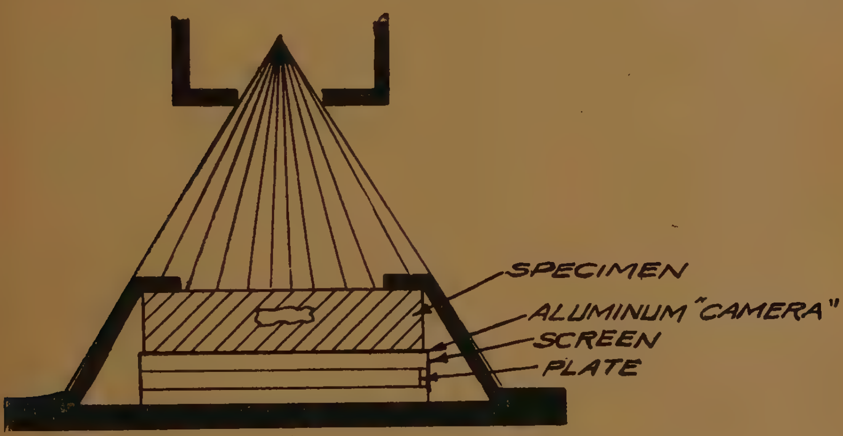


Fig. 4.—Arrangement for protecting photographic plate.

function of the intensity of the rays, that is, of the current passing through the tube. The exposure may then be referred to in terms of milliampere-minutes (ma-min.), at a certain spark-gap (voltage). The limit of ma-min. a tube will stand is determined by the temperature of the target and the heating of the bulb. Most tubes, unless special arrangement for cooling is provided, will carry only 5-6 milliamperes continuously, at the voltage required for this work.

M. H. Pilon describes an experiment in which he successfully radiographed 2.16 in. (55 mm.) of steel by an

exposure of 2 hours and 48 minutes, using a Coolidge tube operating at 6 milliamperes and 120,000 volts.

Davey (Trans. Am. Electrochem. Soc., 28, 410), experimenting with a 15-inch spark gap (150,000 volts) was able to detect defects 1-64th inch thick in 1½ inches of steel with a 60 milliampere-minute exposure, while a 90 milliampere-minute exposure with a 13-in. gap (130,000 volts) was sensitive to not less than 1-32nd inch difference in the same total thickness.

With the best apparatus at present on the market, the metallurgist will be limited to the use of a 10-in. (100,000 volt) spark gap. This will require an exposure of about 3 hours at 5 milliamperes to radiograph 2 inches of metal. This represents the present practical limits of the process. Of course, for purely research work, much higher voltages are available and have been used, making the practical radiography of greater thicknesses of steel a thing to be reasonably looked forward to, but for the present, this is still in the hands of the X-ray tube engineer.

There is another difficulty met with in radiographing greater thicknesses, and that is that any flaws to be detected must be proportionately larger as the piece is thicker, particularly if located at any appreciable distance from the photographic plate. The scattering effect of the large mass between the flaw and the plate will, during the long exposure required, so fog the outlines of the image that it may not be visible, and even though a radiograph can be made, it will not with any degree of certainty show the presence of flaws really existing.

The table gives results of experiments showing the time of exposure under varying conditions which gave good radiographs, and may serve as a practical guide for the determination of the time necessary. Seed X-ray plates were used.

A difference of 50 to 75% in time of exposure may result from different density of the metal and from the character of the defects it is desired to show. This is well illus-

TABLE SHOWING EXPOSURE TIMES FOR GOOD RADIOGRAPHS

Thickness	*Spark Gap*	*Exp. MA-Min.*	*M. A.*	*Distance Source to Plate*	*Remarks*
.375″	10″ (25.4 cm)	10	4.0	11″	No screen
.375″	10″ "	2⅔	4.0	11″	With "
.5″ (12.5 mm)	11″ (28 cm)	7	—	20″	No "
.55″ (14. mm)	10″ (25.4 cm)	128	4.0		No "
" "	" "	30	4.0		No "
.5″ (12.5 mm)	13″ (33 cm)	4	—	20″	No "
.5″ "	15″ (38 cm)	1	—	20″	No "
.56″ (14 mm)	15″ (38 cm)	2.5	1.25	20″	With "
.87″ (21.7 mm)	10″ (25.4 cm)	160	4.0	15″	No "
.87″ (21.7 mm)	10″ "	36	4.0	15″	With "
.95″	10″ (25.4 cm)	60	4.0	15″	" "
1.0″	10″ (25.4 cm)	112	4.0	12″	" "
1.0″ (25.4 mm)	11″ (28 cm)	45		20″	No "
" "	13″ (33 cm)	19		20″	No "
" "	15″ (38 cm)	10		20″	No "
1.5″ (37.5 mm)	15″ (38 cm)	90		20″	With "
2.16″ (55 mm)	10″ (25.4 cm)	650	6.0	?	
*.75″ (19 mm)	10″ "	5.6	2.8	22″	

* Copper.

trated in Figs. 5 and 6, in which the composition of the various rods shown varied less than 1½%.

In developing an X-ray plate, a slow developer must be used, due to the fact that the emulsion, usually thick and carrying a high silver content, is affected all the way through. Too rapid developments would fog the surface and the negative would lose sharpness.

Special X-ray plates, films and developers are now obtainable from reliable manufacturers. Radiographs are usually examined as negatives so that a greater density is required than when prints are to be made.

The relative depth of flaws may be determined either by radiography from two points and calculating the depth (Fig. 7) or by making a stereoscopic radiograph as shown in Fig. 8.

Owing to the severe requirements in the matter of high voltage, currents, and long continued operation, the hot cathode or high vacuum tube gives the most satisfactory results in metal radiography.

The examination of forgings for flaws presents greater difficulties than castings because such flaws usually occur as hair line cracks or lines which, unless they happen to

Fig. 5.—Radiograph of .87" cast steel rods, machined. 10" spark gap, 4 milliamperes, 8 minute exposure with screen.

Fig. 6.—Radiograph of .87" cast steel rods, machined. 10" spark gap, 4 milliamperes, 40 minute exposure without screen.

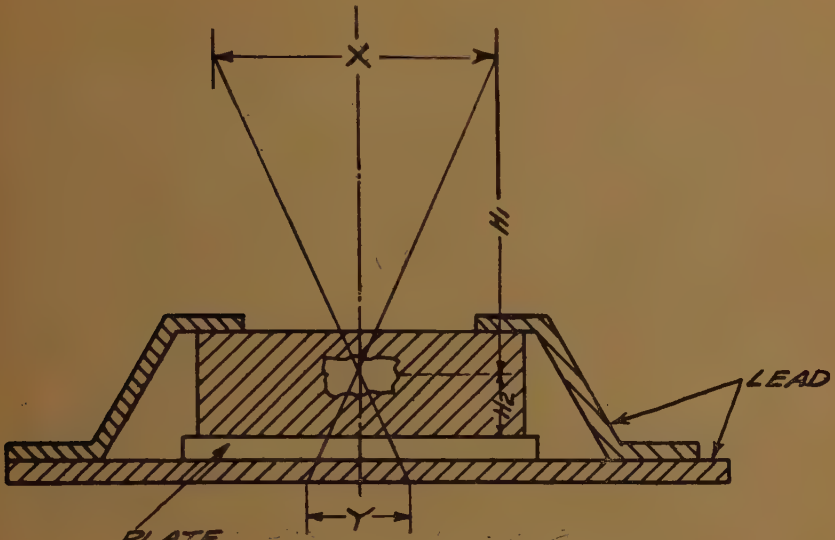


Fig. 7.—Method for determining depth of flaw.

run almost parallel to the path of the rays and in a straight line, would not be visible on the negative. Even under these favorable circumstances, differences in density, due to these defects, are difficult to detect, for the

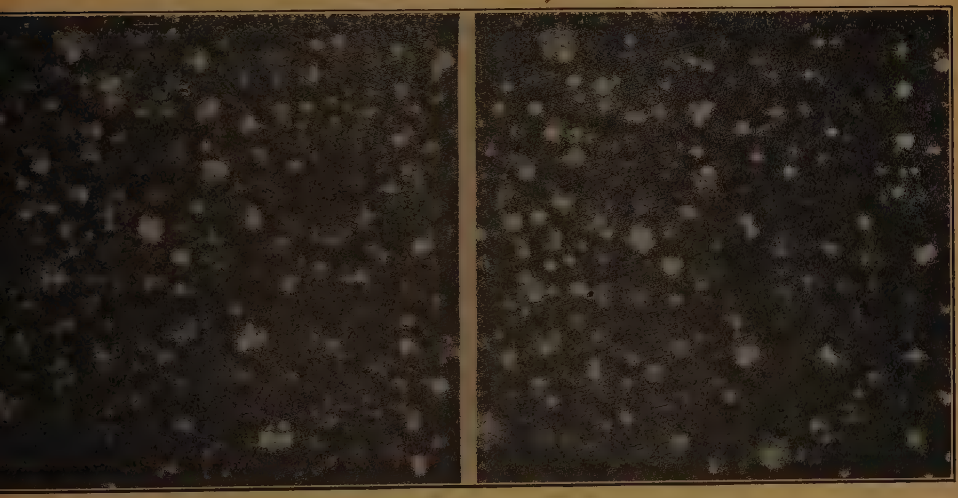


Fig. 8.—Stereoscopic radiograph of portion of a block of copper. When viewed through a hand-stereoscope this shows the size and relative depths of the pores.

Fig. 9.—Radiograph of ¾″ steel plate, .0065″ slit ⅛″ above photographic plate (positive).

Fig. 10.—Radiograph of ¾″ steel plate, .0065″ slit on side away from photographic plate (positive).

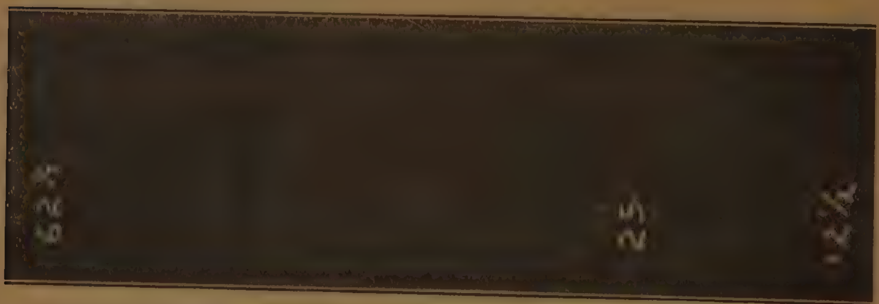


Fig. 11.—Radiograph of ¾″ steel plate, slit next to photographic plate.

radiograph does not enlarge and shows only such defects as would be visible if exposed to the naked eye.

In order to determine the thickness of the smallest air inclusion which could be distinguished radiographically, two plates of steel were machined and ground to flat surfaces. In one of these a slot was cut to give a wedge of air of varying thickness. Each plate when finished was 5/8 in. (15.5 mm.) thick. The two steel plates were then bolted together and radiographed at 15 in. (38 cm.) gap. In this manner it was found that an air inclusion .021 in. (.5 mm.) could be detected in 1¼ in. (32 mm.) of steel and an air inclusion .007 in. (.2 mm.) could be detected in a total thickness of 5/8 in. (15.5 mm.) of steel. This is, of course, under the most favorable conditions, when it was known beforehand that the inclusion existed and just where it was.

A similar experiment made with a thinner wedge is illustrated in Figures 9, 10 and 11. The thickness of the slot in mils. is indicated by the figures on the radiograph. In this case a total thickness of ¾ in. was used, and we

Fig. 12.—Radiograph of sheath wire (positive).

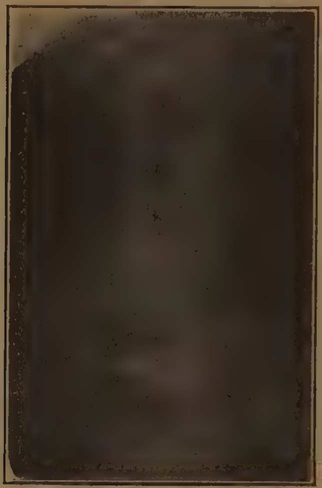


Fig. 13.—Radiograph of electric weld (negative).

Fig. 14.—Radiograph of electric weld (negative). Note dark line of weld, visible only after surface was polished.

Fig. 15.—Radiograph of electric weld.

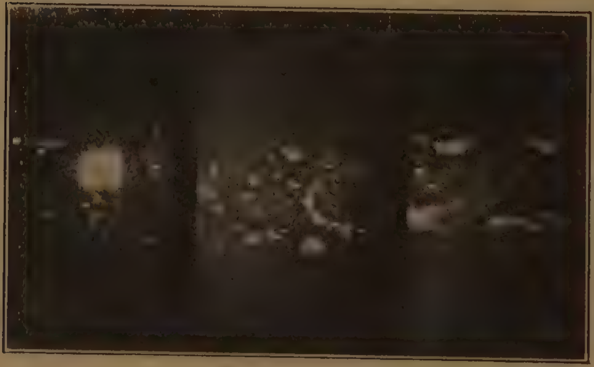


Fig. 16.—Radiograph of electric weld.

find that when the inclusion is near the plate a thickness of .014 in. may be distinguished. When 1/8 in. from the plate a slightly greater thickness is necessary and when on the side away from the plate the air inclusion must be at least .030 in. thick to be detected under the most favorable conditions.

Figures 5 and 6 show blow holes in steel castings .87 in. (21.7 mm.) thick. Figure 12 is a radiograph of a sheath wire in which the core wire is of nichrome and the sheath of mild steel with magnesia insulation between them. Figures 13 to 16 are radiographs of electric welds, show-

Fig. 17.—Blowholes in rejected iron casting (negative).

ing the imperfections due to lack of joining and inclusions. Figure 17 shows blowholes in a rejected iron casting.

To summarize: From the point of view of those who are interested in the metallurgical application of X-rays, the following conclusions may be drawn:

(1) The practical application of metal radiography in the work-shop, bearing in mind time of exposure and available apparatus, is at present limited to about 1½ in. of steel.

(2) For purely research purposes and with special apparatus, somewhat greater thicknesses are possible of successful examination, but the results are increasingly harder to obtain and more difficult of interpretation as the thickness increases.

(3) Only such inclusions as would, if exposed, be visible to the naked eye can be detected; hence the detection of hair line cracks or of very small sonims is very uncertain.

The author wishes to express his indebtedness to Dr. W. P. Davey, whose pioneer work in this line has been made liberal use of in this paper.

President Gary: We will have the discussion of Mr. Ruder's paper by H. S. Rawdon of the Bureau of Standards, Washington, D. C.

METAL RADIOGRAPHY

Discussion by H. S. Rawdon
Bureau of Standards, Washington, D. C.

The clear explanation of the production and nature of X-rays and the definite and explicit description of their use in the radiography of metals just given, leaves very little to be said concerning the technique and manipulations necessary for success in this particular application in the study of metals. In general, the results of the work along this line done by the Bureau of Standards confirm those described by Dr. Ruder. The Bureau has been limited to apparatus of the 100,000 volt (10″ spark gap) type mentioned, hence it has not been possible to attempt readily, with any hope of success, the examination of specimens of steel whose thickness exceeded one inch. Most of the examinations have been made upon specimens considerably less than this in thickness. Of course with lighter metals and alloys, e. g., aluminum and its light alloys, much thicker specimens may be used and very satisfactory results obtained. In the study of this class of metals the method appears to offer more possibilities than in the field of iron and steel. It is believed that some of the applications made at the Bureau of Standards of metal radiography, working within the limits outlined by Dr. Ruder, are suggestive and interesting enough to warrant a short description here.

In the study of "flaky" steel, with which most of us, unfortunately, are familiar, it was desired to follow the behavior of material known to be defective through a series of heat treatments without mutilating the material in any way. The claim has been made repeatedly that proper heat treatment alone is sufficient to remedy the defect known as "flakes." Fig. 1 shows a series of radiographs of a specimen of gun steel (carbon, 0.38; nickel,

2.92; chromium, 0.20) after different heat treatments. The specimen, which was a transverse radial section of a finished gun tube forging, was ⅜″ in thickness. The three white circular spots were produced by drilling holes of the size shown nearly half way through the specimen; these were needed as reference points for locating the various features revealed by the examinations. The four radiographs represent the material in the following con-

(a) (b) (c) (d)

Fig. 1.—Flaky gun steel examined by X-rays after various heat treatments. The specimen was placed so that the direction of the rays coincided with the plane of the defects. Each white line represents a flake. The three white circles are reference points made by drill holes partly through the specimen.

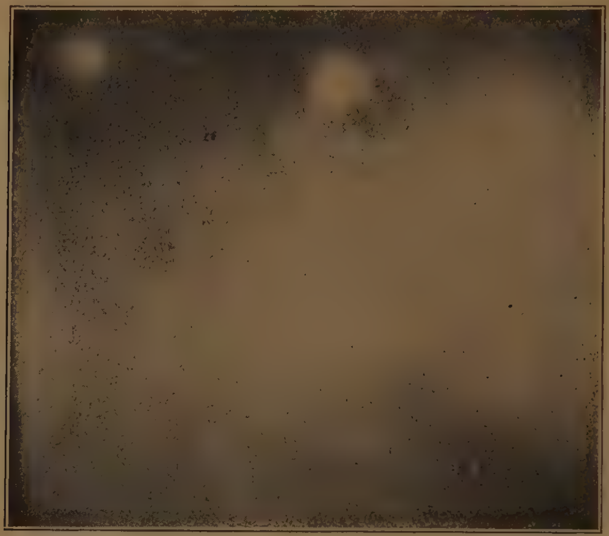
(a) Finished forging, as received. (b) Same after annealing 30 minutes at 900°C. (1475°F.) and cooling in the furnace. (c) Same after heating 30 minutes at 900°C. (1475°F.) and quenching in oil. (d) Same after heating 30 minutes at 1050°C. (1915°F.) and quenching in oil.

Note the increase in number and indefiniteness of the white lines. Exposure—9″ spark, 2 milliamperes, 7 minutes.

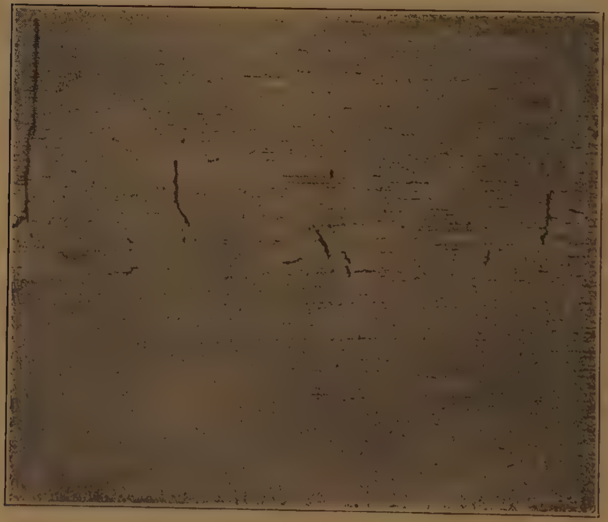
ditions: (a) the finished forged gun tube as received; (b) after annealing for thirty minutes at 900°C. (1475°F.) and cooling in the furnace; (c) after heating in a barium chloride bath for thirty minutes at 900°C. (1475°F.) and quenching in oil; (d) after heating for thirty minutes at 1050°C. (1915°F.) and quenching in oil. The series of radiographs show the gradual opening up of the defects. In many of the flakes in the initial or forged specimen the

metal on the two sides of the separation was in such intimate contact that the intensity of the transmitted rays at the point was practically the same as that of those which passed through the adjacent sound metal, hence no evidence of the flakes was recorded on the photographic plate. The behavior of the defects during vigorous heat treatment is shown by the increase in number and in definiteness of the white lines in the radiographs, which change can be due only to an increase in the width of the separation or fissures. The same method is to be used in the further study of this material to show the behavior of flakes in defective material when it is mechanically worked.

A similar application was attempted in the study of transversely fissured rails. The deep etching by means of concentrated acid of sections cut from the head of rails which have developed transverse fissures in service shows the presence of very serious defects such as are illustrated in Fig. 2. The presence of these defects in the material before etching had never been demonstrated and as a result a grave difference of opinion as to their seriousness and real character existed. Longitudinal slices, ¼″ in thickness, cut from the head of a rail were examined by means of X-rays in the endeavor to locate such defects before the specimen was etched. Although the piece was known to contain these defects and their location had been definitely established by means of a magnetic method, no trace of their presence could be obtained by the X-rays. This confirms the third conclusion of Dr. Ruder that the detection of defects which, if exposed to view, are invisible to the eye, is very uncertain, if indeed *any* indication is obtained. The method by which the defects were located in specimens, previous to etching, was to polish the surface as for microscopic examination, magnetize the piece, and then bath it in a light oil, e. g., kerosene, containing fine iron dust in suspension. Whereever a discontinuity in the metal exists a change in the density of the magnetic flux results and the particles of



(A)



(B)

Fig. 2.—Longitudinal section of transversely fissured rail head showing interior fractures. (A) Interior fractures revealed by deep etching with hot concentrated hydrochloric acid. (B) Same specimen as A before etching. The defects have been located by magnetizing the specimen and then immersing it in kerosene containing fine iron dust in suspension. X-rays failed entirely to reveal the presence of these defects.

iron arrange themselves so as to outline the shape of this discontinuity. Of course, this method can be applied only to the detection of defects which extend to the surface. Fig. 3 shows the appearance of interior fractures located by this means. Although an actual discontinuity exists, as was shown by cutting out sections and breaking

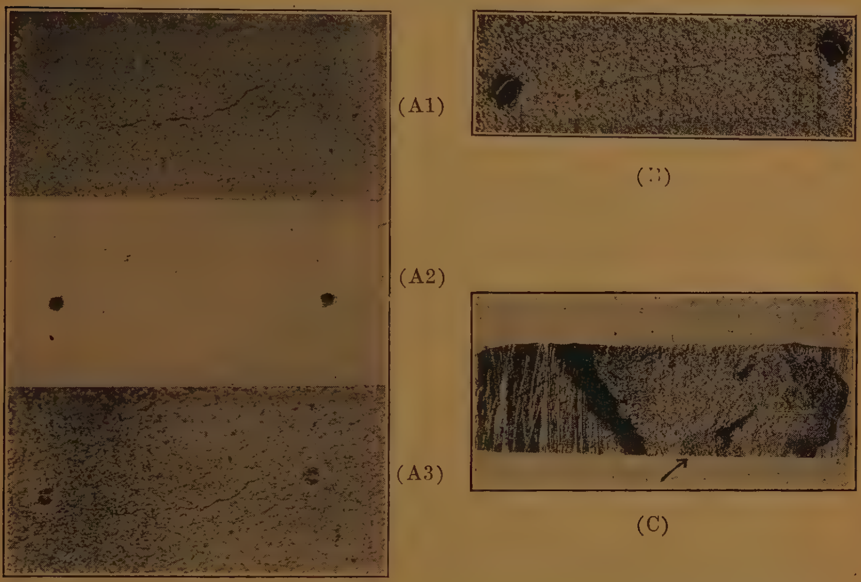


Fig. 3.—Nature of the defects in transversely fissured rail heads. (A1) Defect similar to those shown in (Fig. 2A), located in the magnetized specimen by fine iron dust in suspension in oil. (A2) Same specimen, after locating the defect by a punch mark at each end and then wiping off the iron dust. (A3) Same specimen, retreated with iron dust. x3. (B) Similar defect which has been opened up by means of two punch marks. The defect is really an internal fracture, the metal was in very intimate contact. x10. (C) Similar specimen. The material was broken transversely to reveal the interior fracture. It was impossible to locate these defects by means of radiographic examination.

them in two, and of such an extent that it must be regarded as a very serious defect, the metal is still in such intimate contact along the plane of the separation and the face of the separation is so irregular in its contour that the transmission of the X-rays here is the same as that through the adjacent sound metal.

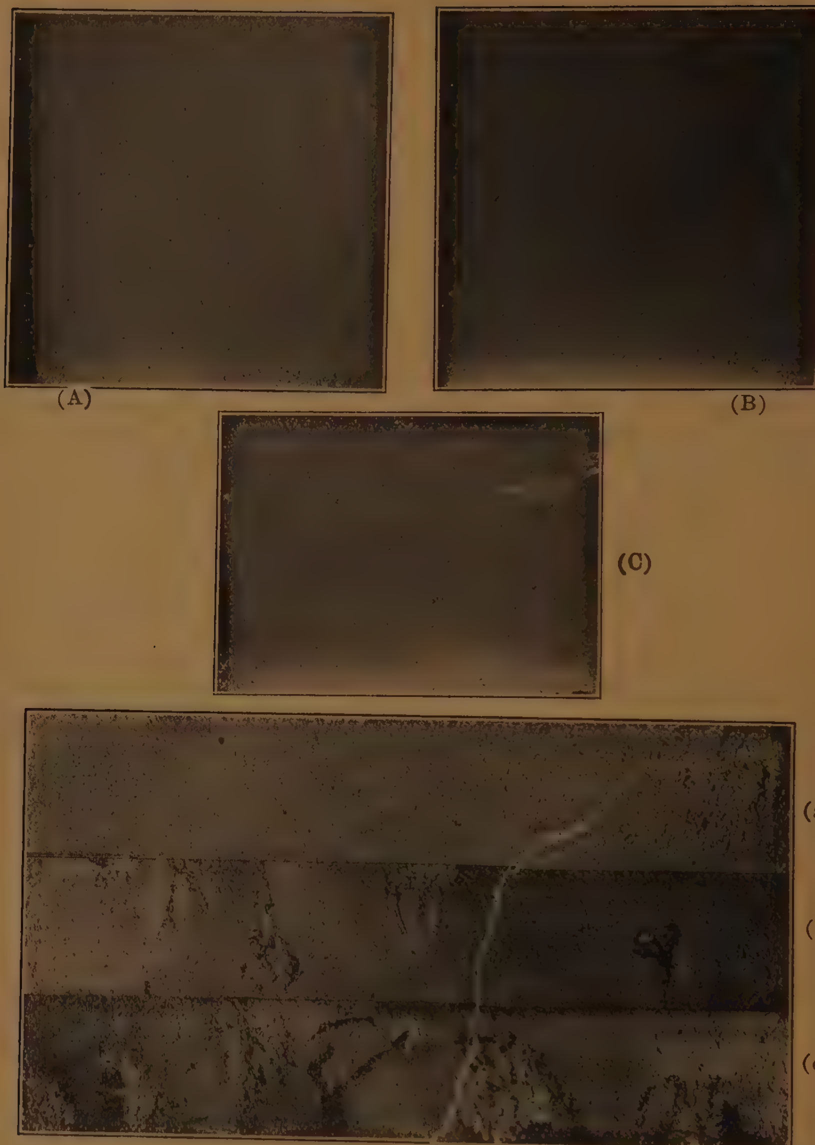


Fig. 4.—Radiographic examination of test specimens and the corresponding fracture produced in fatigue tests. Gun steel similar to that shown in Fig. 1 was used.

(A) Radiographic examination revealed no flakes. (a) The fracture of the fatigue test specimen has the smooth porcelain-like appearance characteristic of sound material. x2.

(B) The white lines correspond to interior flakes. (b) The coarsely crystalline areas in the face of the fracture are evidence of flakes. x2.

(C) The specimen contains numerous hidden flakes. (c) The appearance of the fracture corresponds to the condition of the interior as revealed by the X-rays. x2.

Conditions of exposure were similar to those of Fig. 1.

Another application was made of X-rays in the study of specimens which were to be tested as to their behavior under reversed stresses, i. e., fatigue tests. The interior condition of three typical specimens which are of the shape and size for the Upton-Lewis machine is shown in the radiographs of Fig. 4 (A, B, C). In this case as before, the specimen was so placed that the path of the rays was parallel to the plane of the flake. The type of fracture produced in the fatigue test for each class of steel is shown in Fig. 4 (a, b, c). As might be expected the material showing no evidence of the flakes broke with a smooth porcelain-like fracture, the others show large conspicuous crystalline areas in the face of the fracture corresponding to the flakes. This application of radiography to the examination of test specimens, particularly those tests which are expensive either from the viewpoint of the time required to carry one to completion or of the extreme care which is required in shaping the test specimen, is probably one of the most important applications which can be made of metal radiography. In the investigation of arc-welded materials now in progress at the Bureau of Standards it is proposed to examine all specimens for the impact and the fatigue tests in this manner in order to locate any serious defects such as are quite common in welded materials which would vitiate the results of the test.

Other applications of the method have been made, mainly of a miscellaneous character, however. One such examination was of complex mixtures such as copper-lead bearing metals in which the fineness of the grain of the mixture which can be detected by X-rays is very surprising. Another instance worthy of mention is the examination of a small ingot too thick for the X-rays (as available at the Bureau) by means of the radiations from radium. The presence of an enclosed pipe was indicated by the radium-radiograph obtained. It is believed, however, that the most interesting and helpful work has been along the two lines described, i. e., the effect of various types of treatment upon hidden defects and the prelimi-

nary examination of specimens intended for test purposes.

The Division of Metallurgy of the Bureau is greatly indebted to the co-operation and help of Dr. Dorsey by whom the radiograph examinations were made.

President Gary: Mr. R. L. Sanford, physicist, Bureau of Standards, Washington, D. C., will speak on the "Magnetic Analysis of Steel."

MAGNETIC ANALYSIS OF STEEL

R. L. Sanford
Physicist, Bureau of Standards, Washington, D. C.

Magnetic analysis may be defined as the utilization of magnetic methods for the study of the internal structure and mechanical condition of magnetic materials and in particular of iron and steel. It may be used to detect structural changes on heating or cooling or as an indication of mechanical properties. The results of magnetic analysis are to be interpreted in the light of the best available knowledge of the correlation between the magnetic and other properties of materials.

Many physical and chemical methods for testing steel and steel products destroy the sample or render it unfit for the use for which it was originally intended. This fact has made necessary our present methods of vicarious testing. It is plainly evident, therefore, that any satisfactory non-destructive method which makes possible the comparison of each individual piece with one whose performance has been carefully determined and which thus serves as a standard of quality will have great commercial value.

The mechanical properties of steel are functions of its chemical composition and of its micro-structure and mechanical condition. The micro-structure and mechanical condition, such as internal strain, etc., are determined by the thermal history and the amount and kind of mechanical work that has been done on the piece. The magnetic properties of steel are likewise functions of the same variables and any change produced in one set of properties is accompanied by a corresponding, though not necessarily proportional, change in the other.

Fig. 1 shows graphically the relations between the quantities measured during the course of a complete mag-

netic test. If a magnetically neutral or demagnetized piece of steel is subjected to an increasing magnetizing force, the resulting induction is indicated by the curve OTD. If the magnetizing force should only be brought up to the point T and afterwards reduced, and then increased to the same value in the reverse direction, the curve TRCE is traced where values at the left of the axis represent magnetizing forces in the reverse direction.

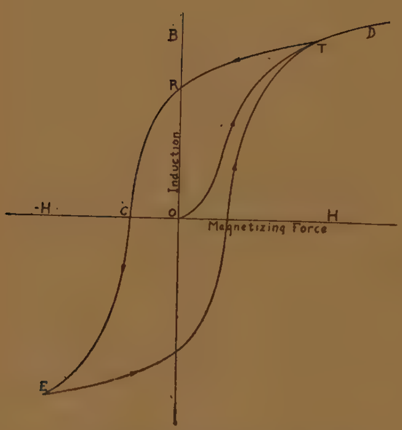


Fig. 1.—Showing normal induction and hysteresis curves for steel.

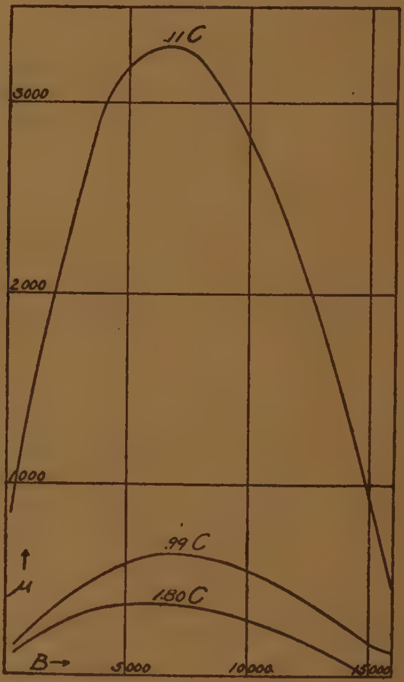


Fig. 2.—Showing the variation of permeability with induction for steels of different carbon content.

If the magnetizing force is again reversed, a closed loop is traced as shown. This loop is called the hysteresis loop and its area is proportional to the energy required to take the steel through a complete magnetic circle. The value of induction corresponding to the point R is known as the residual induction and the value of reversed magnetizing force required to reduce the induction to zero, repre-

sented by the point C, is called the coercive force. The point T, representing the maximum value of magnetizing force and induction for a given hysteresis loop is called the tip of the loop. The ratio of magnetic induction to the corresponding magnetizing force at any point on the curve OTD is called the magnetic permeability.

It is too long a story to present at this time in any detail the results of many experiments which have shown the existence of a close connection between the magnetic properties of steel and the factors determining its mechanical properties. We may consider three cases which are illustrative of the effect on the magnetic properties of chemical composition, hardening and tempering.

Fig. 2 shows the variation in permeability of annealed carbon steel with various carbon contents. It will be noted that the permeability varies through a rather wide range as the carbon content varies from .11% to 1.8%, decreasing as the percentage of carbon is increased.

The next diagram (Fig. 3) shows the effect of heat treatment on the magnetic properties of a 1% carbon steel. Note particularly the difference between the effect of quenching in water and oil.

The curves of Fig. 4 show the effect on the coercive force of drawing or reheating a 1% carbon steel after quenching. Note the clear evidence of the transformation in the case of the water-quenched steel which took place between 200° and 300°C. The transformation evidently took place during the quenching when oil was used as the quenching medium, due to the slower rate of cooling through the critical range.

While the evidence already at hand is sufficient to demonstrate that there is a very strict correspondence between the magnetic and mechanical properties of steel, these relationships are so complex, that up to the present time no definite laws have been worked out. Indeed it may prove extremely difficult, if not impossible, to completely define in terms of the magnetic properties of a substance all of its other physical properties. In spite of

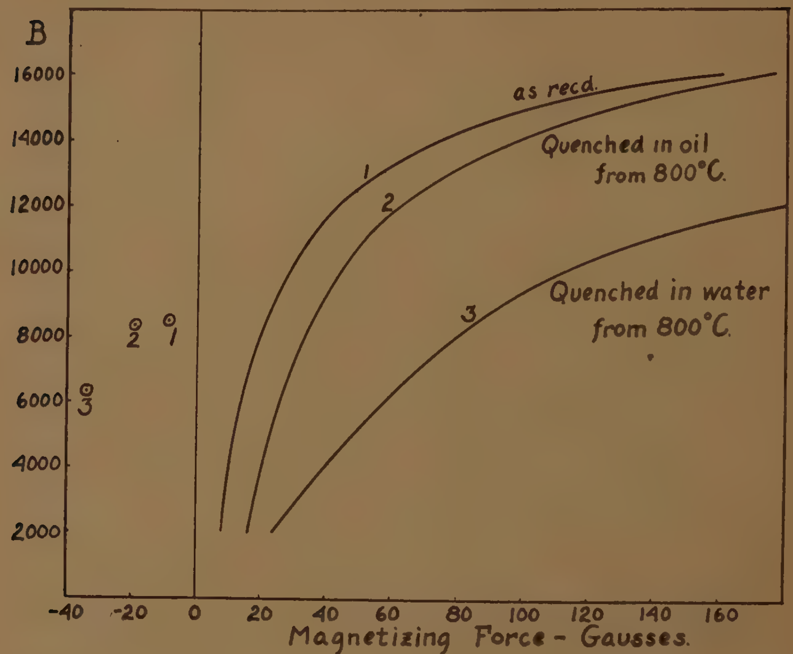


Fig. 3.—Showing the effect of heat treatment on the magnetic properties of a one-per-cent. carbon steel.

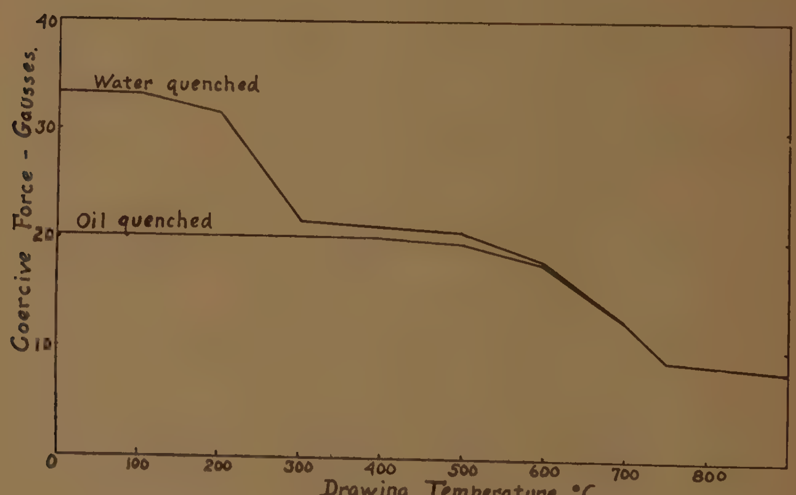


Fig. 4.—Showing the effect on the coercive force of drawing a one-per-cent. carbon steel.

this apparently discouraging fact, we need not wait for the complete working out of all the correlations before applying magnetic analysis in a practical way.

The methods of magnetic analysis may be employed either by the investigator, as an aid to the solution of theoretical problems such as those arising in the study of the phenomena involved in the hardening of steel, or by

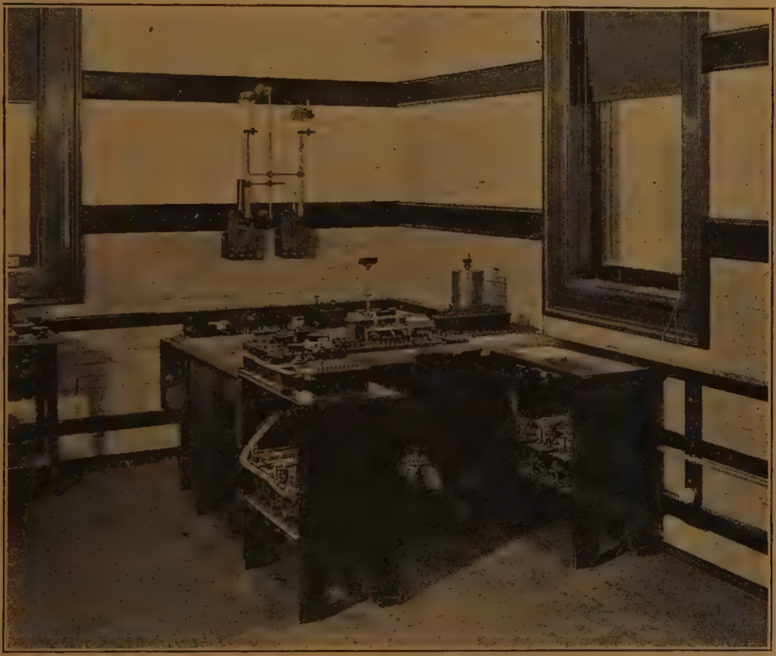


Fig. 5.—Standard permeameter at the Bureau of Standards.

the testing engineer, as a non-destructive method of test to supplement the methods already in use.

A laboratory such as the Bureau of Standards is admirably adapted to the study of this subject from the theoretical standpoint and the Magnetic Laboratory of the Bureau is at present carrying on investigations of this nature. This work is being done in co-operation with other divisions of the Bureau and in particular with the

Division of Metallurgy. This work is not yet sufficiently far advanced to present definite results, but they are very promising and indicate that the method may be expected to yield very valuable data which will serve not only to advance our theoretical knowledge, but also to provide a foundation on which practical applications may be based.

Fig. 5 shows a corner of the Magnetic Laboratory and

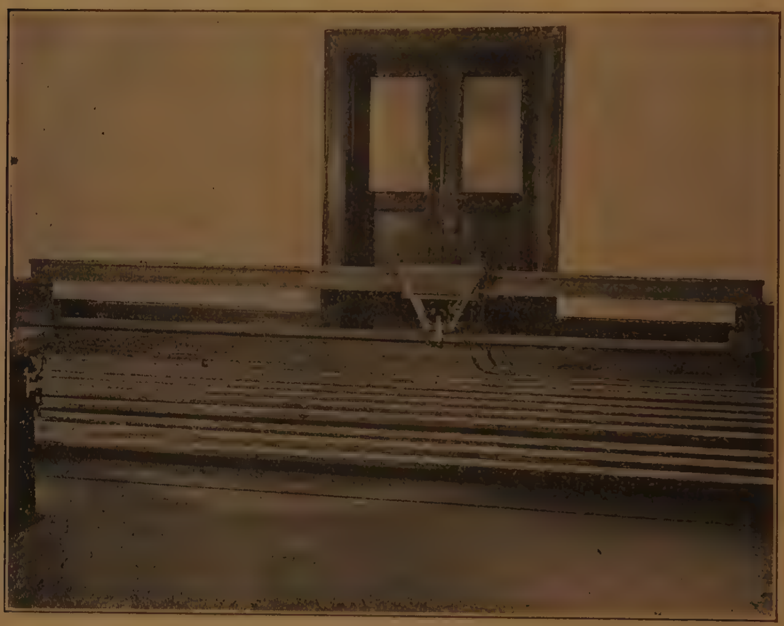


Fig. 6.—Rail testing apparatus.

the apparatus used for making standard tests of the magnetic properties of specimens of iron or steel.

For practical purposes, magnetic analysis has as its ultimate object the development of methods and instruments which can be used in the shop for the purpose of comparing the factory product with specimens which have been selected as standards of quality. At the present stage of development, each application must first be the subject of an individual investigation. The properties

of the material must be studied, the magnetic criteria for quality must be determined upon and apparatus must be built for making the magnetic measurements quickly and accurately under shop conditions. After these steps have been completed, the final step is trial under actual service conditions to demonstrate that the method is sufficiently rapid, accurate and reliable to warrant its commercial use.

The magnetic laboratory has developed a method for determining the degree of magnetic uniformity along the

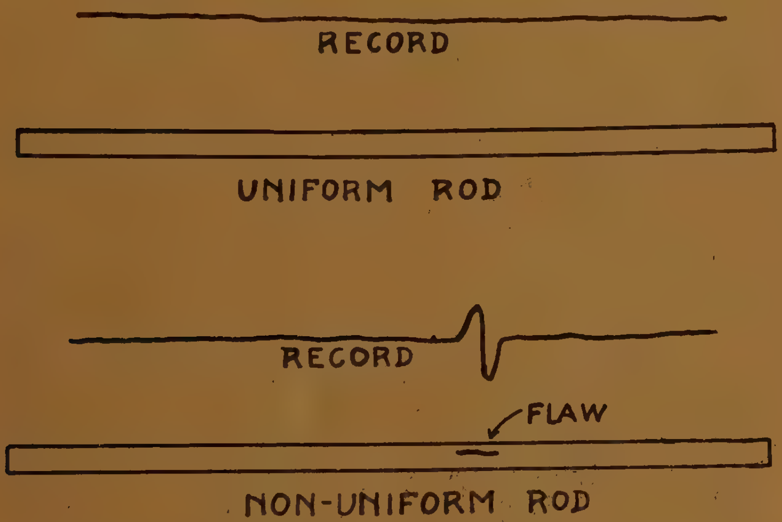


Fig. 7.—Type of photographic records showing degree of magnetic uniformity of steel bars.

length of a specimen of substantially uniform cross section. This method has been adapted to the study of steel rails. Part of the apparatus for testing rails is shown in the photograph of Fig. 6. The test consists of surrounding the rail with a magnetizing solenoid which is run along the rail. A sensitive electrical instrument which is connected to a test coil carried with the solenoid indicates any change in magnetic permeability of the specimen as the coil moves along. The type of records obtained by photographic means is shown in Fig. 7.

Fig. 8 shows apparatus as constructed for the testing of rifle barrel steel and Fig. 9 shows a flaw which was detected by a magnetic test.

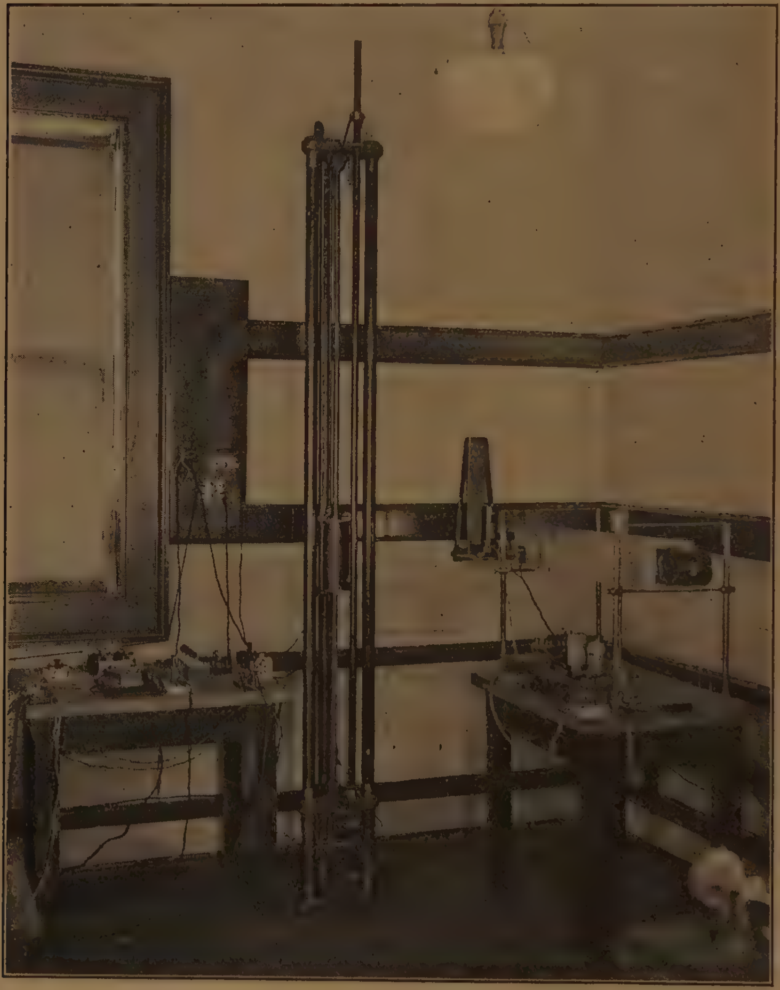


Fig. 8.—Apparatus for testing rifle barrel steel.

The greatest difficulty in this line of investigation lies in the interpretation of the results. This is due to the fact that there are many causes that may produce magnetic inhomogeneity, such as chemical segregation, strains

and flaws, and it is difficult to differentiate between them. The conclusions so far warranted are: (1) A bar which is magnetically uniform along its length is also mechanically uniform. (2) A bar which is mechanically non-uniform along its length is also magnetically non-uniform and this non-uniformity will be surely indicated by the test. (3) Bars which are magnetically non-uniform may

Fig. 9.—Flaw detected by a magnetic test.

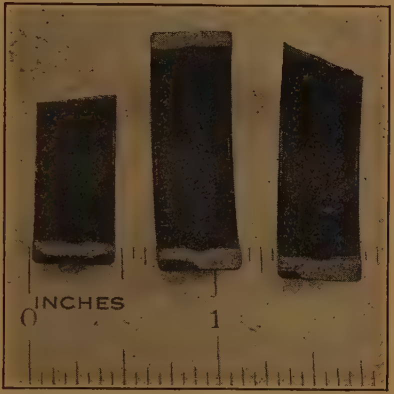


Fig. 11.—Showing cracks in ball bearing races detected by magnetic analysis.

or may not be seriously defective from the mechanical point of view.

This last conclusion points out the necessity for further investigation which is being carried out in co-operation with the Ordnance Department of the Army.

A method is in process of development for the testing of ball bearing races. The work is not yet complete but it has been demonstrated that the apparatus is capable of detecting flaws, such as hardening cracks in the rings.

The apparatus used is shown in Fig. 10. The ring is mounted on a table free to rotate and magnetized between the poles of an electromagnet which also rotates,

The rotation of the ring is opposed by a spiral spring. By means of a pointer and scale the torque exerted on the ring by reason of the rotation of the electromagnet can be measured. This torque is proportional to the energy required to carry the direction of magnetization of the

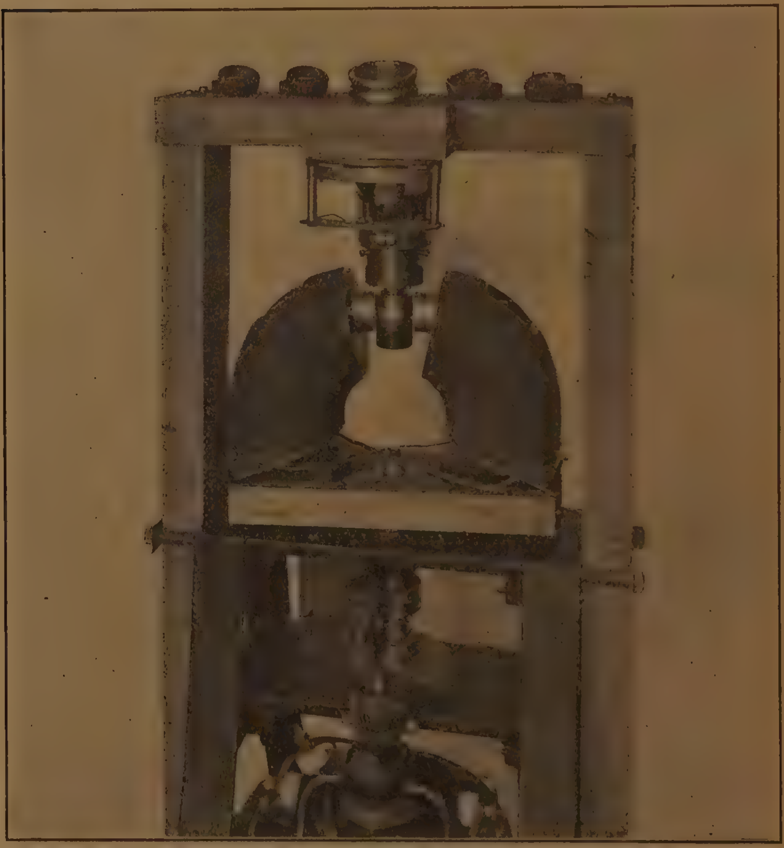


Fig. 10.—Experimental apparatus for testing ball-bearing races.

ring through one complete revolution. It seems probable that this value may be used as an index in testing the rings. If the needle jumps during the rotation a crack or soft spot is indicated. The cracks shown in Fig. 11 were detected in this manner.

Fig. 12 shows apparatus used in preliminary experiments on twist drills. The drills shown in Fig. 13 were first given a magnetic examination and then drills A and B were subjected to identical service tests. The coercive forces for these drills were in the ratio of 3 to 2, the higher value indicating the better drill.

To sum up: The work already done has furnished sufficient evidence of a very strict correspondence between

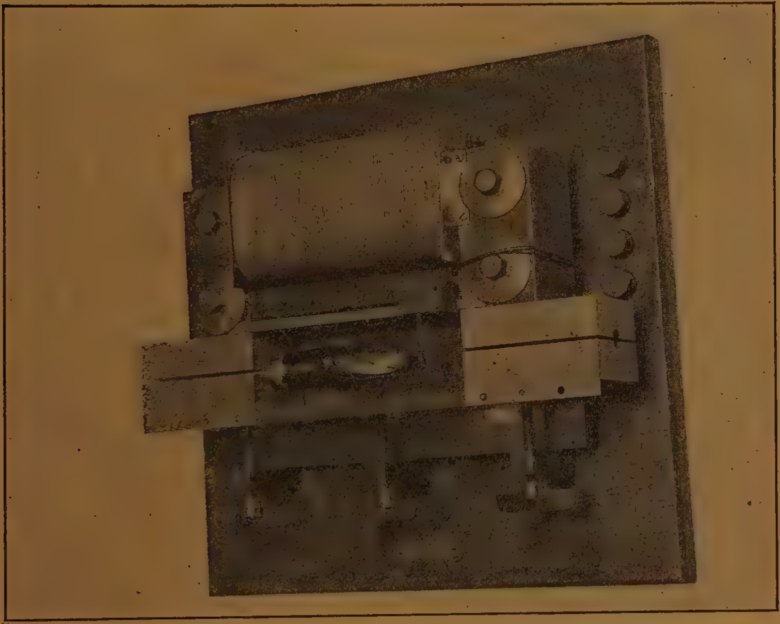


Fig. 12.—Experimental apparatus for testing twist drills.

the magnetic and mechanical properties of steel to warrant the conclusion that magnetic methods may be used to advantage in fundamental investigation and for non-destructive testing of steel products which obviously will have very great commercial value.

The possibilities seem to be almost unlimited. Any one connected with the manufacture of steel and steel products can easily bring to mind many applications which if satisfactorily worked out would make possible large savings in material and manufacturing costs.

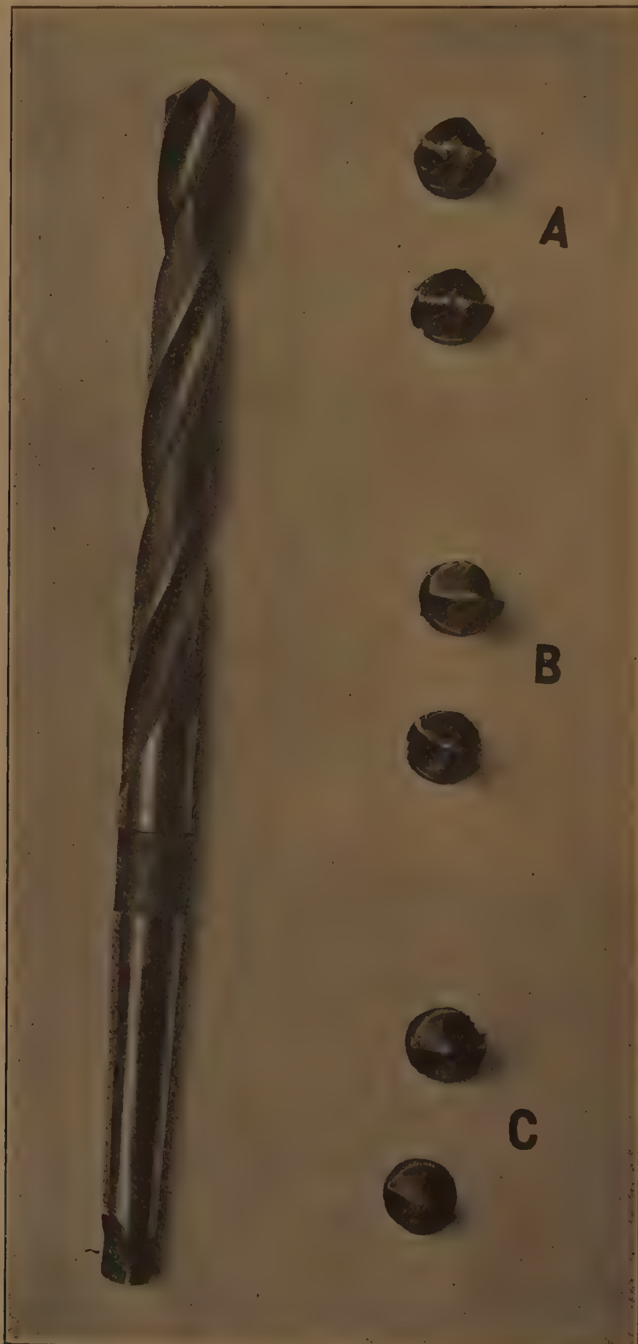


Fig. 13.—Showing results of service test on twist drills.

The future development of magnetic analysis must progress along the two lines of fundamental research and practical application since the proper interpretation of the results requires a full and complete knowledge of the existing relationship and this knowledge will have practical utility only as it is actually applied to the study and control of the structure of steel and the inspection of finished products.

And finally, the best progress can only be expected as the result of sympathetic co-operation between all those interested from whatever point of view.

President Gary: Mr. Sanford's splendid paper will be discussed by Professor Henry M. Howe, Bedford Hills, New York.

THE MAGNETIC ANALYSIS OF STEEL

Discussion by HENRY M. HOWE
Professor Emeritus of Metallurgy, Columbia University, New York.

Mr. Sanford brings out clearly two distinct fields for magnetic testing, first, a magnetic comparison between rails, eye-bars or other products which we do not wish to destroy on the one hand, and, on the other hand, test pieces cut from crop ends which we do destroy by means of our tensile and impact tests. Each lot is accepted or rejected as a whole on the destructive physical test of coupons or other test pieces. Then each rail, eye-bar, etc., of the lot is compared with those test pieces magnetically and without injury. Any rail which differs magnetically from the test piece is either rejected, re-treated, or subjected to special scrutiny.

This test should detect any deviations in the rails from the quality of the test piece, caused either by heat treatment, mechanical treatment, segregation, or error in composition.

Second, a uniformity test, applicable most easily to pieces of uniform cross section like rails, wire, cables, etc. These may be passed rather rapidly by the magnetic testing device, which should indicate all important flaws and inclusions. Any suspicious rails or parts can then be examined exhaustively, perhaps by X-rays, perhaps by resonance tests, perhaps by electrical resistance tests, in extreme cases even by density tests.

To apply either of these magnetic tests to a forging, prior to machining, might save great loss of time and money by preventing the machining of defective forgings. Though such tests should be applied most easily to pieces of uniform cross section, they might easily be modified so as to apply to those of varying section. A single master piece, such as a gun forging, proved by exhaustive

tests to be sound, and of the desired composition and thermal and mechanical treatment, would give a master curve in the comparison and uniformity tests. All duplicates of this forging should give curves like this master curve, and all which do not should be re-treated, re-tested or rejected. Steel intended for surgeon's instruments might well be tested magnetically.

I have in passing suggested the X-rays as supplementary to the magnetic tests. This would seem to be their proper function. The whole product of a mill could be tested magnetically with little cost, whereas the X-ray test is so tedious that it should be applied only to parts already shown by other means to be suspicious, and to pieces of such importance that every precaution should be taken to detect defects.

I found great interest in X-ray testing in England, where I attended a very enthusiastic meeting of the Faraday Society, called by Sir Robert Hadfield and devoted wholly to this subject.

The X-rays thus far give nothing but a shadow test, which can detect small inclusions and flaws only in case they are in the immediate neighborhood of the photographic plate, and hence only when they are near the surface of the piece. Large inclusions and flaws nearer the centre of large pieces should be detected more readily by other means.

None of these tests promises to be able to detect alumina resulting from the use of aluminum, for this is likely to form very thin discontinuous films, which in rolling and forging become rather evenly distributed. Its fusibility prevents its coalescing into considerable masses. Should not its use in making important products, on which life depends, be forbidden with severe penalties?

THE SECRETARY: There are here three prominent English gentlemen identified with the iron and steel industry whom I have never had the pleasure of meeting. If they

will be kind enough to make themselves known to me, I shall be glad on behalf of the Institute to try to make their visit with us pleasant.

The director's meeting will be held in the room just at the north end of this room. A luncheon for members will be served in the Grand Ballroom.

If you have a lady with you, be kind enough to report the fact at the secretary's office at the end of the lobby. We would like to show them the courtesy of providing them with tickets to the gallery for this evening. The space is not very large and therefore we are unable to give any one member many tickets, but we hope and believe that we will be able to take care of all of the ladies with you.

President Gary: Gentlemen, if there is no objection, we will adjourn until two o'clock.

Recess was then taken. At two o'clock Judge Gary called the meeting to order.

President Gary: The first paper this afternoon is by Mr. Wilfred Sykes of the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pennsylvania, entitled "Electrically Driven Reversing Rolling Mills."

ELECTRICALLY DRIVEN REVERSING ROLLING MILLS

Wilfred Sykes

Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.

We are becoming so accustomed to the use of electric machinery in our daily life that sometimes the significance of the change from past practice is not appreciated. I believe this is true to some extent in regard to the electrically driven reversing rolling mill which has been quite extensively used in the last few years, and it is the object of this paper to briefly review the factors that led up to its development and use, and to summarize the present state of the art.

Perhaps a brief historical review will be of interest when considering the development of this class of equipment. The idea to use electric motors for driving rolling mills was first exploited in Europe where a number of small equipments were installed, beginning about twenty years ago. These were all used for driving mills running in one direction, and the machines were of the types already developed for other purposes. The ease with which the extension of the plant could be cared for, and the freedom from restrictions as to distance from the boilers was quickly appreciated, even before the economical advantages of electrification were realized. The concentration of the generating equipment into large units of the highest economy, with the corresponding reduction in total capacity required and a very much higher average load, together with the fact that the distribution loss is trifling and varies with the load, was not given consideration until a later date.

About 15 years ago, the number of machines installed had grown considerably, and about this time a start was made in this country when two 1500 H.P. motors were

built for driving the No. 3 rail mill at Edgar Thomson Plant. The problems involved in the design of such plants as Gary required a radical change from past practice, and the advantages of electric drive having been more clearly developed in the meantime, it was natural that electricity should be the medium for transmitting the energy from the power plant to the wide spreading mills which could then be distributed solely with regard to the proper handling of the material.

Since then the development has been rapid and the great majority of new mills in the last ten years have had electric drive.

Application to Reversing Mills

With regard to the electrification of a complete steel plant, there was for a number of years a big question as to the possibility of using motors for reversing mills. Many steel men felt that the motor was all right for continuously running mills and could appreciate the economic advantages, but when it became a question of a reversing drive on, say, a blooming mill, they felt that it was questionable, and that perhaps the safe course would be to use the old-fashioned steam engine. A few years has changed all this, so that today the electrically driven reversing mill is comparatively common, and there is no longer any question of its ability to do the work and do it economically.

The electrically driven reversing mill had a simultaneous development in Europe and America, the initial installation in Europe having been made a little ahead of that in America, but the work was entirely independent. We will confine ourselves to the plants on this side of the water in this discussion, but it might be well to mention that for a time the development was more rapid in Europe owing to a quicker appreciation of the advantages and economic conditions that favored the construction in Europe when practically nothing was being built here.

There are two questions that must occur to any one

having to decide the type of power to be used in his mill. They are:

(1) Will the type of drive meet all the requirements of production?
(2) Will it be the most economical that will satisfy the first condition?

Production carries with it all questions of reliability, ease of operation and the fitting of the characteristics of the drive to the requirements of the mill. Economy covers all items of cost, such as fixed charges, power cost, labor, maintenance, stores, etc., so that an answer to these two questions satisfies the usual mill man.

There is one other factor, not quite so tangible, but of the greatest importance in the development of a plant, and that is the question of layout. We do not have to seek very far for examples of the restrictions that power distribution has had on mill layouts with the accompanying congestions and consequent greater cost of handling materials. With the use of electricity, we suffer no practical restrictions so that our plants may be laid out with regard only to the facility for transportation of materials and, although this does not show itself directly in costs, when the plant as a whole is taken and compared with others, very gratifying results are obtained.

The reversing motor has been used for all types of reversing mills and to date has not found its limitations. Blooming mills, billet mills, plate mills and structural mills have all been electrified with success. The first installation put in operation 12 years ago at the South Works of the Illinois Steel Company drove a 2-high universal plate mill, and I feel that it is only proper to pay a tribute to the foresight and courage of those responsible for the decision to make this initial experiment. The co-operation of the mill engineers with the manufacturers led to a successful plant which has given excellent service to date, and will undoubtedly do so for many years to come. For many years this plant stood alone, and there

were still doubts in the minds of many regarding the ability of a reversing motor to drive a blooming mill which might well be described as the heart of a steel mill. It was recognized that the work was hard and reliability was of the utmost importance, even more important than economy. It remained for our neighbors in Canada to carry out the first successful blooming mill drive, and all honor is due to Mr. Robert Hobson of the Steel Company

Fig. 1.—General view of reversing motor and flywheel motor generator set of Steel Company of Canada, Hamilton, Ontario.

of Canada for taking the responsibility of tying up his new plant to the comparatively untried electric drive, especially in view of a rather unfortunate experience of another plant that made a similar experiment. I believe that it is safe to claim that this installation has been a success and it was the forerunner of the numerous plants that have been built since, many of the earlier installations having been made on the basis of data so generously supplied by this plant.

Mechanical Construction.

The principal part of an electrical reversing drive is, of course, the motor connected to the mill. These motors are direct current machines and differ little in general characteristics from those with which we have been long familiar. There are, however, many special features that play a most important part and that spell the difference between success and failure. Of first consideration must be the mechanical construction and this must be beyond question. We must make a closer study of the details of construction than is usual to insure there can be no relative movement of parts under the severe shocks that the motor has to stand, and prudence requires that all parts be so strong that in case something must break about the mill, it will not be the motor. Together with this, we must keep our design balanced so that the weights of our moving parts are not excessive, as an appreciable amount of energy is required to accelerate and retard the motor itself. Good engineering requires that, like the famous "one horse shay," each part shall be as strong as the other, and all equal to the requirements of the mill. This, of course, presupposes a knowledge of mill requirements by the electrical designer, and the success of this type of installation has been mainly due to such studies as we have made over a period of many years.

The motor is not supplied with energy direct from the power plant, but through a so-called "flywheel motor generator set." The function of this set is to provide means for controlling the speed and direction of rotation of the motor, and of equalizing the load on the power plant. It would be, of course, very difficult to build any type of controlling equipment that would handle the large current involved in motors of this type, as will be readily appreciated when we think of the flashing and noise made by the controllers for the motors driving the tables, screw down, etc., which seldom exceed 100 H.P., whereas our main motor may carry loads 100 times as great. The speed of the motor is proportional to the voltage im-

pressed on it, and its direction of rotation depends on the way the current flows through it. By having a special generator to supply the motor, we can, through the excitation of this generator, vary the voltage and the direction of the main current, and we need handle only about ½ of 1% of the current in the motor. This is, of course, easily done and the control of our 10,000 to 20,000 H.P. motors is actually better than the control of the table motors.

The second function of our flywheel set is to prevent the terrific peak loads from the mill from being thrown on the power plant. If this were not done, it would be necessary to have large generating capacity running at very low average load to carry the mill. Fortunately, we can equalize the load to a great extent by a properly controlled flywheel which will give up energy during periods of great demand and absorb it during the intervals. For this reason, suitable flywheels are connected to the generators supplying power to the reversing motor and through the aid of suitable controlling apparatus, they are utilized so that the load on the power plant is only about one-fourth of the peaks on the main motor.

For driving the generator and flywheel, some kind of motor is required, and the type is dependent on the power system. This motor is only large enough to carry the average load and is not concerned with the peaks of the mill motor. The remainder of the equipment is for the purpose of controlling these functions and providing means for measuring and recording the power used. The starting and the control of the speed of the motor driving the set is done by the slip regulator, which automatically slows down the flywheel during peak load, thus causing it to give up energy, and accelerates it during intervals, thereby absorbing energy.

This may seem a rather round-about system, but it functions admirably, and it does more than a steam engine, inasmuch as it equalizes the load, which is of the greatest importance from an economic standpoint.

Electrical Design.

Brief reference has been made to the mechanical construction of the equipment. The electrical design is of equal importance and it has been through studying mill conditions and the operation of machines built in the past that we are today able to state with confidence that we can not only equal engine performance, but improve upon it, and do it at a fraction of the cost of power. There are innumerable details that have been worked out and improvements made which were all required to make

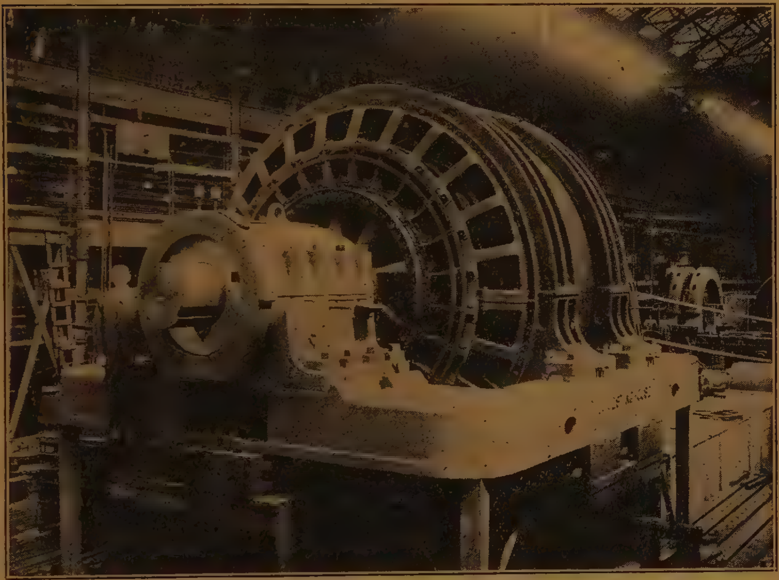


Fig. 2.—Reversing motor (15,000 H. P.) being tested in the factory.

a successful drive, and today we can look back on our initial technical difficulties with a feeling that a long road has been successfully traveled and something accomplished of benefit to the industry.

Today we have 28 mills running successfully and a number have been built for shipment to France, Japan and India. They are connected to the best products of our mill builders and may be truly said to represent our best practice.

Numerous investigations have been made of their work, and it is hoped at a later date to publish this data for the benefit of the industry. As an appendix to this paper is given a list of the reversing drives built or building by American manufacturers, which may be of interest to any one desiring further information. The accompanying illustrations give a good idea of the appearance of some of these equipments.

I will not attempt to give any figures at the present time showing performance of electrically driven mills, as without the fullest details such figures are misleading. In regard to production, it is sufficient to say that investigations we have made of records show that electric drive in all cases is able to hold its own with the best of past practice, and there is ample evidence to show that with the elimination of restrictions in the mill, better performance can be obtained. As to the first cost, the reversing motor and equipment is a little more expensive than a high class engine, all factors considered, but the fuel required does not exceed one-third of that for the average engine, and is less than one-half of that for the best engine we can build. Such items as labor, maintenance, etc., are very small, so that altogether it shows great economy compared with steam drive.

We are accustomed to associate a considerable boiler plant with a reversing engine and it is rather interesting to find that with electric drive the power taken by the reversing motor, compared to the mill auxiliaries, is not greater than it is. A five-month average of one plant shows that the main blooming mill equipment took only 2¼ times the power required for the auxiliaries of the same mill. This, of course, is simply a confirmation of the figures given before, but when we keep in mind the picture of the boiler plant required for a reversing engine and the relatively small equipment for the auxiliaries, we can appreciate that the electric drive must be economical, when the power used is not much more than twice that for the motors driving the tables, manipulators, screw downs, etc.

Cost of Operation.

This brings us to one of the most important factors in considering electric drive, and that is, we must consider the power problem of the plant as a whole. It is not reasonable to take a part of a mill and make a comparison of cost of electric versus steam drive, especially where the steam plant may be an isolated unit, as we unduly load the electric motor with a part of the generating plant out of proportion to the real facts. It is where we consider the plant as a whole that the electric system demonstrates its value.

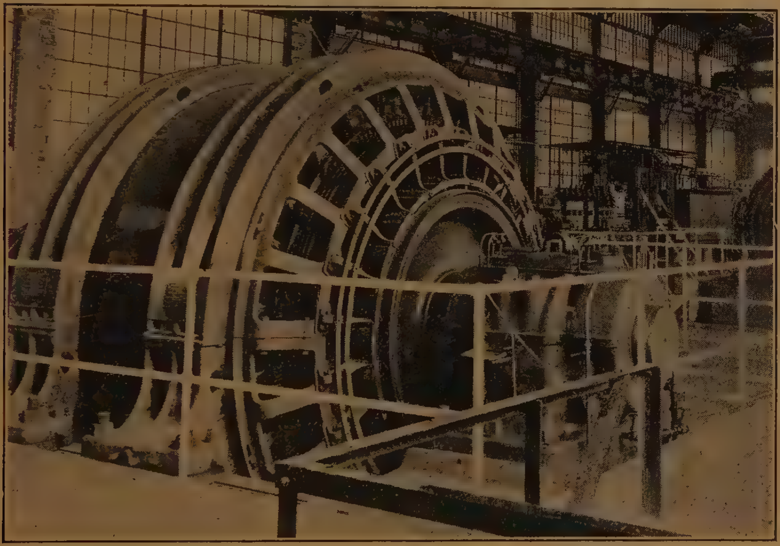


Fig. 3.—Reversing motor (15,000 H. P.) at plant of United Alloy Steel Corporation, Canton, Ohio.

No one questions that the most economical method of making any article is to specialize the plant, installing the best equipment and manufacturing in large quantities. With reasonable distribution costs, such an establishment will eventually supplant the isolated small manufacturer. The whole history of our industrial development bears this out. And so it is with power generation. For economy, we must concentrate our power equipment

so as to utilize the best that science provides us with. By using large units, the greatest economy is obtained, and the relative labor and other costs are reduced to a minimum. If we then connect to such a power generating station all our power consuming devices, we will find that the aggregate required is less than the sum of the loads on the individual consumers. It is the same as having a diversified market for our products, a dullness in one locality is compensated for by a demand from another, and in this way our average output is maintained approximately constant, which is obviously the most economical condition. If we had to support individual factories to supply all local demands, we would in the aggregate have a capacity out of proportion to our total output. Efficient distribution is the solution in the case of our manufacturers, and with power, electricity provides the economical means for transporting our power to the consuming devices. The ideal we must work to is to generate our power wholesale and distribute it efficiently. Electricity provides us with a means of using the most economical prime movers, and the consuming devices can be driven with machines that will transform our wholesale generated power to mechanical work with a loss of only a few per cent. It is with such a picture in mind that we must consider electrification of our mills and we then see that electricity is the ultimate means of transportation of our power if we are to utilize our resources to the best advantage. We not only convert more of the heat units in our fuel into useful energy, but we can arrange to take advantage of the overlapping of the fluctuations of the demand of our consuming devices to average them and so keep the rate of generation approximately constant.

With the experience now available, it is beyond question that our power distribution in the future will be by means of electricity, and we should lay out our generating stations with units of such size and characteristics in relation to the ultimate requirements as to get the best economy, and with such a margin of capacity that the

electrification of our plants can take place as opportunity offers, without having to consider each time we desire to add a motor whether the generating plant will not have to be extended. We can then modernize our mills as changes are required and ultimately convert our wasteful methods of power generation of the past to the best that we have at present knowledge of. Great force is given to this viewpoint with the rapid rise of fuel and labor costs, two of the principal factors in our power costs. It is wise in this respect to consider the possibilities of ultimately tying different generating stations together for the material benefit of those concerned. In this way, power may be interchanged at times to advantage and the stand-by value of such interconnection reduces the amount of spare plant required with the consequent savings.

With electrically driven reversing mills, we can generate our power in the most economical manner possible and transmit it to the mill coupling, allowing for all conversions, with a loss of about 25%.

The much greater economy of the prime movers used makes this loss relatively neglible, and the net result is as previously stated.

In the next few years, there will undoubtedly be a great deal of reconstruction in our mills to improve economy. The electric motor provides a means of solving power questions. The great central stations are now alive to the possibilities of steel mill loads, and in many cases provide a solution. In the case of the larger plants, we can expect to see the generation of power given more attention, and this will mean specialization, so that our power making department will be given equal consideration with the departments of the plant concerned with more direct production.

President Gary: There will be a discussion of Mr. Sykes' paper by Mr. D. B. Rushmore, engineer, Power and Mining Department, General Electric Co.

LIST OF REVERSING ROLLING MILLS WITH ELECTRIC DRIVE BUILT IN THE UNITED STATES

Company	*Size & type of mill.*	*Max. H.P. of reversing motor, full speed*	*Mill Builders*	*Manufacturer of electrical equipment.*
Illinois Steel Co....................	48" Univ. Plate	8000	United Eng. & Fdry. Co.	Westinghouse
Steel Co. of Canada................	34" Bloom	10000	United Eng. & Fdry. Co.	Westinghouse
Algoma Steel Co....................	35" Bloom	8000	Mackintosh, Hemphill & Co.	Allis-Chalmers
Central Steel Co....................	34" Bloom	8000	Mesta Machine Co.	Westinghouse
Bethlehem Steel Co................	35" Bloom	12000	Mackintosh, Hemphill & Co.	Westinghouse
United Alloy Steel Corporation.....	35" Bloom	12000	Mackintosh, Hemphill & Co.	Westinghouse
Inland Steel Co.....................	40" Bloom	15000	Mackintosh, Hemphill & Co.	Westinghouse
Inland Steel Co.....................	32" Structural	8000	Mesta Machine Co.	Westinghouse
Inland Steel Co.....................	28" Structural	8000	Morgan Eng. Co.	Westinghouse
National Tube Co..................	40" Bloom	15000	Mesta Machine Co.	Westinghouse
Illinois Steel Co...................	40" Bloom	15000	United Eng. & Fdry. Co.	Westinghouse
Ashland Iron & Mining Co..........	36" Bloom	8000	United Eng. & Fdry. Co.	General Electric
Steel & Tube Co. of America........	35" Bloom	15000	Mackintosh, Hemphill & Co.	Westinghouse
Steel & Tube Co. of America........	42" Univ. Plate	8000	Mackintosh, Hemphill & Co.	Westinghouse
Steel & Tube Co. of America........	29" Billet	5000	Mackintosh, Hemphill & Co.	Westinghouse
Keystone Steel & Wire Co...........	36" Bloom	8000	United Eng. & Fdry. Co.	General Electric
American Steel & Wire Co...........	24" Flat	3000	American Steel & Wire Co.	Westinghouse
Penn Seaboard Steel Corporation....	84" Plate	8000	Nat. Roll & Fdry. Co.	Westinghouse
Trumbull Steel Co..................	36" Bloom	12000	United Eng. & Fdry. Co.	General Electric
National Pressed Steel Co...........	24" Univ. Plate	3000	Nat. Roll & Fdry. Co.	Westinghouse
Tubes de Vincey....................	34" Bloom	7200		Westinghouse
Bethlehem Steel Co.................	40" Bloom	12000	Mesta Machine Co.	General Electric
Sharon Steel Hoop Co...............	34" Bloom	8000	Mackintosh, Hemphill & Co.	Westinghouse
Universal Steel Co..................	28" Plate	3000	Mackintosh, Hemphill & Co.	Allis-Chalmers
Tenn. Coal, Iron & R. R. Co.........	40" Bloom	15000	Mesta Machine Co.	General Electric
Brier Hill Steel Co..................	84" Plate	8000	United Eng. & Fdry. Co.	Westinghouse

LIST OF REVERSING ROLLING MILLS WITH ELECTRIC DRIVE BUILT IN THE UNITED STATES

Company	*Size & type of mill.*	*Max. H.P. of reversing motor, full speed*	*Mill Builders*	*Manufacturer of electrical equipment.*
Lackawanna Steel Co.	32″ Rail	15000		General Electric
Bethlehem Steel Co.	60″ Univ. Plate	17500	Morgan Eng. Co.	Westinghouse
Tata Iron & Steel Co.	40″ Bloom	15000	Mackintosh, Hemphill & Co.	General Electric
Imperial Steel Co.	40″ Bloom	10000		Westinghouse
Auto Berliet	34″ Bloom	8000	Treadwell Eng. Co.	Westinghouse
Bethlehem Steel Co.	44″ Bloom	15000	Mesta Machine Co.	Westinghouse
Imperial Steel Works	50″ Slab	17500	Morgan Eng. Co.	Westinghouse
Follansbee Brothers Co.	30″ Bar	5000	Nat. Roll & Fdry. Co.	Westinghouse
Algoma Steel Co.	40″ Bloom	15000	Mesta Machine Co.	Westinghouse
Algoma Steel Co.	35″ Roughing, Rail and Structural	8000	Mesta Machine Co.	Westinghouse
Algoma Steel Co.	28″ Rail and Structural	8000	Morgan Eng. Co.	Westinghouse
Dominion Foundries & Steel	40″ Univ. Plate	5000	Mackintosh, Hemphill & Co.	Westinghouse

ELECTRICALLY DRIVEN REVERSING ROLLING MILLS

Discussion by David B. Rushmore
General Electric Co., Schenectady, N. Y.

When we have an opportunity of looking back from the standpoint of some future year on the age in which we are now living it will stand out very distinctly for several important facts: (1) the enormous rate of progress of the development of what we call industry, the transformation of raw materials into those products that man wants for ultimate consumption; and (2) intimately connected with the first, the use of energy in other forms than man-power for the transformations thus brought about.

Unless we have taken especial pains to see it, but few of us realize the importance of the fact that we are drawing our natural sources of energy for all of the products of industry from horsepower hours of energy; that every suit of clothes, every locomotive, every rail, every part of an industry contains so many horsepower hours of energy, and without that our civilization could not exist on the plane on which it does exist.

Among these industries, as you gentlemen know so much better than anyone else, there is none more important than the steel industry. There is no industry that is more important for the wants of man, if separated from the luxuries, than the industry which furnishes so much of the machinery of production. In that industry the power obtained from natural sources must be taken to the places to be used and must be applied in the most convenient, safe and economic manner; and that is and has been the function of electricity, the most convenient and economical form in which to apply power.

In applying electric power to the steel mills, and I

hesitate very much to try to tell you gentlemen much of the long, interesting story, with which many of you that I see before me are quite as familiar as an electrical manufacturer can be, there has necessarily been, as in everything else, an evolution. Business and labor and social life, as we are finding, is founded on one thing; man is the unit with which we largely deal, and the psychology of man is the very important factor which we have to consider. In introducing electrical machinery into the various fields the psychology of the industry and the psychology of the individuals in it plays a very important part and possibly people from an allied industry can see the effects quite as plainly.

The steel industry is made up of men, first of all desiring results, desiring reliability, and accustomed in their minds to rapid changes in methods, to progress. If there is one word that applies to it more than anything else, it is progress; the habit of mind of rapid progress, of throwing away the old, of replacing it with the better, the new, and of introducing electrical power, as it is now almost universally used in installations of this kind; the engineer of the steel mills, the presidents, the officials, the operators, have all contributed very largely to the result.

Electrical manufacturers in the main industrial fields in which they work have been very fortunate in having the active and effective co-operation of the men in the industries, and as new engineering questions have arisen, as the necessity on the part of the electrical manufacturer for determining with accuracy and precision the facts concerning the application of electrical machinery has made itself apparent, he has had a very able and close co-operation from men in the industries.

There has probably been no industry in this country in which electricity has been applied so successfully as it has in this particular one; the number of mistakes that have been made have been extremely small, the general satisfactory result of the installations has been very high,

and it has been in part due to the co-operation and in part due to the fact that fortunately electricity is something easily measured and handled, together with the mechanical features with which it is involved, in a way very thoroughly known; that is, in applying an electric motor to a steel mill the most uncertain factor is the power required on the ingot, the inertia of the moving parts (the characteristics of the machine itself are all well within the hands of the engineer who handles it), and while some of the results have seemed somewhat startling perhaps, and very interesting, in connection with the magnitudes involved, it is a field in which a minimum number of uncertainties exists.

The very great increase in the application of electricity to the steel industry has brought about a rapidly increasing importance of this department of the work in all industries, and a very proper recognition of the functions of the men in the industry handling this work. The wonderful work in connection with safety, in which, as you know, Judge Gary and the Steel Corporation have played such a very prominent part, has reacted most decidedly on the electrical part of the work. The idea of safekeepers is employed in designing and installing, as well as in operating apparatus, and this has contributed not a little to its very great success.

I would not be fair if I did not speak in this connection of the interests with which I have been involved in a very active work, and if I did not mention the name of Mr. Hawley, who has taken such a very active part in all of the steel mill work from its very beginning.

In the introduction of electrical machinery we have done and are doing something which must have our consideration. Labor is composed as we know of two elements: the energy supplied, the power; and the mental, the brain or intellect.

As electrical machinery is more and more introduced and as man's physical activities are curtailed, certain very elusive, important and dangerous psychological

phenomena begin to appear. Men of every kind desire expression, and psychologists are coming to realize that the man who thinks, but who does not act, is having taking place within himself certain nervous disturbances which may outwardly result in some undesirable forms of activity.

The future of electrical machinery in its application to steel mills is very great. Motors are fairly well developed. Progress is being made continuously. The forms used in some of the mills require a very complete understanding of the electrical phenomena involved. The greatest opportunity for development in electrical machinery, as well as in human beings, is in the function of control, of automatic control, so that the machinery runs, after it is once started in operation, stimulated by the load conditions and not by externally introduced forces of man. Progress along this line is rapid and the field of the future is very great.

In closing I think it would be perfectly fair if I took upon myself the expression of the entire electrical industry in expressing an appreciation of the great pleasure which it is to work in this field, of the very hearty co-operation which electrical manufacturers have met from the engineers of the steel industry, and the very great promise which we are looking forward to as new metallurgical problems in the rolling and the handling of steel are worked out and as new modifications of electrical apparatus and appliances are required.

President Gary: We will now have further discussion of Mr. Sykes' paper by Mr. J. E. Fries, of the Tennessee Coal, Iron & Railroad Co., Birmingham, Alabama.

ELECTRICALLY DRIVEN REVERSING ROLLING MILLS

Discussion by J. Elias Fries

Chief Electrical Engineer, Tennessee Coal, Iron & Railroad Co., Birmingham, Ala.

Mr. Sykes' experience with the electrification of steel mills is as long as the art itself, so that there are few men so well qualified to speak with authority on the subject as is Mr. Sykes. He has today given us a paper in which he broadly and ably outlines the principles and advantages of the electrically driven reversing mills.

As to the advantages of electrification, the electrical engineer has always found it difficult to state in dollars and cents the reasons why electrical drive is preferable to steam drive. Nevertheless, the necessary proof has been furnished by the installations themselves, which certainly is the best proof possible, so that it is extremely unlikely that there ever will be another steam driven reversing mill installed.

It is probably not primarily the saving of fuel which has forced this verdict in favor of electrification, but a great number of secondary advantages, so to speak, which experience has demonstrated to us; such advantages, for instance, are: smaller cost of upkeep and greater facility of operation, enabling us to train operators in far shorter time than was the case in the steam driven mill. The necessary number of highly skilled workmen can be materially reduced in the electric mill. It must not be forgotten, either, that the great reduction in noise and the comparative absence of soot and dirt in the electric mill has had a beneficial influence on production.

Mr. Sykes states that there are already twenty-eight reversing mills, electrically driven, in successful operation on this continent. While the fundamental design of

all these electric drives is the same, they differ in various minor respects from each other and it may be worth while to point out a few of these differences.

They all employ the so-called "Ilgner System," where the reversing motor unit consists of one or more direct current motors. This unit receives its current from generators driven by an induction motor in a motor generator set and a suitable flywheel is interposed between this motor and the generators in order to smooth out the load-peaks. Reversing and changes in speed are accomplished by reversing and varying the excitation of motor and generators. It is not exactly clear why it should be necessary to make and break the large excitation current in the modern blooming mill drive. Considerable energy is also lost in the resistance units through which this excitation current passes. It would appear that the same end could be accomplished with less wear and tear and smaller loss in the field circuit of the exciter itself. The only possible objection as far as I can see is the loss of time in the magnetic circuit of the exciter, but this objection is theoretical only as the loss of time is such a minute fraction of a second.

The conductors connecting the generators with the motor unit become very large in the modern blooming mill. For instance, in the forty-four inch blooming mill recently installed at the Fairfield Works of the Tennessee Coal, Iron and Railroad Company (which, by the way, is the largest electrically driven reversing mill installed so far) these conductors have to carry current peaks as high as twelve thousand amperes. When carrying such currents, the conductors, if placed twelve inches apart, attract or repel each other with a force amounting to six hundreds pounds per foot. These conductors must therefore be thoroughly braced, which fact I mention because I have seen in some places a continuous bending back and forth of the conductors in question, threatening to break the insulating supports, in which case disastrous short circuits may take place.

With such large conductors it would appear desirable to connect them solidly, that is, without any break from generator terminals to motor terminals.

In some of these installations, however, each of these leads is taken through another small commutator machine which therefore has to carry all the load currents flowing from the generators to the motor. The purpose of this machine is to furnish an excitation current proportionate to the load current, and this excitation current is superimposed upon the primary excitation of the reversing motor in a separate winding. Thus the reversing motor becomes a compound motor, that is, it slows down under increased load.

The advantages of all these complications are hard to understand. The mill operator does not desire the mill to slow down under load; on the contrary, as soon as the ingot has entered the mill, the operator desires the mill to speed up and he does speed it up by use of the control apparatus with which he is provided for that purpose. It is said, however, that the compounding effect saves the mill from over-strain. But it is evident that the greatest strain in the mill occurs when the ingot enters the rolls. The motor, however, does not know when this happens and compounding cannot take effect until the entrance of the ingot already has slowed down the mill somewhat, but then the mill has already suffered its greatest stresses and the compounding effect arrives post festum.

If control takes place directly in the field circuit of the generators and the motors, there should be many cases in which a separate motor generator set for the purpose of excitation could be dispensed with altogether. Wherever direct current is used for auxiliary drives in the mill and the source of this direct current is reliable and of constant potential, there is no good reason why the excitation current for the reversing drive should not be taken from the station bus bars. In the case of the Fairfield blooming mill a separate exciter set has not been

installed and I believe our mill is unique in this respect.

The Fairfield blooming mill is driven by a reversing motor unit consisting of two complete motors on the same shaft, each with a rated continuous capacity of 2,800 H.P., or a combined capacity of 5,600 H. P. The unit is capable of developing peak loads as high as 22,000 H.P. and on six ton ingots 16,000 H.P. peaks are normally required for every ingot.

I am glad that Mr. Sykes has given such a prominent place in his paper to one particular benefit inherent in electric drives, namely, that it enables us to produce our energy in large quantities. We can never sufficiently emphasize the importance to the industry and to the country as a whole of carrying as diversified a load on our power stations as is obtainable and of concentrating our power production to as few points as possible, and further, to interconnect these power stations with each other so as to obtain the further benefit of territorial diversification. It is not only a question of coal saved behind boilers and water saved behind dams, but it is also a question of eliminating the necessity for installing separate spare genertor units at each and every place where important electric installations are in operation.

In order to carry out this program, however, it will be necessary for the steel industry to abandon the twenty-five cycle frequency and adopt sixty cycles and fortunately the art has so advanced that nothing prevents us today from making this move.

If we steadfastly keep the goal before our eyes we shall undoubtedly make a noteworthy contribution toward the conservation of our natural resources.

President Gary: There are two other discussions, which have been reduced to writing, and leave will be given to print and publish them without reading.

ELECTRICALLY DRIVEN REVERSING ROLLING MILLS

Discussion by Robert Hobson
President, Steel Company of Canada, Hamilton, Ont.

Mr. Sykes has referred to the reversing motor which we have in operation at our blooming mill and I have been asked to say a few words with regard to its operation.

This motor has been operating since March, 1913, during which time it has rolled 1,353,879 tons of various sizes, varying from 10″ rounds down to 4″ x 4″, the average size being about 5″ x 5″.

From an operating standpoint, this equipment has given practically no trouble, as is illustrated by the fact that in the last 4½ years, which period is given so as to eliminate the development period during which time several changes were made, the total delays charged by the Mill Department against this equipment was 11 hours and 35 minutes, which is roughly one minute delay for every 2000 tons rolled. A further analysis of the above shows that there is only one hour and 35 minutes delay which is chargeable to operation of this equipment, which takes care of breaking in new men to operate the motor for the mill and the maintenance of the controlling apparatus.

The one outstanding feature which is of great importance is the low labor cost, as this equipment can be attended by one operator per shift. When one considers that the power consumption per ton is only three times that consumed by the auxiliary motors, driving tables, shears, cranes, pumps, etc., that is, all the other power used in this mill, it is obvious that the actual power consumed is low.

The average total cost, including power, light, operation, maintenance, plant overhead charges and all auxiliary machinery over the period of 6½ years during which

this equipment has been operating is 23.8 cents per ton, which represents an average consumption of 22.3 K.W. hours per ton for main drive, or a power cost of 13.9 cents per ton.

Detailed figures, as presented in the paper read by Mr. Jefferies, our electrical engineer, before the Association of Iron and Steel Electrical Engineers in 1916, for three years' operation of this mill, show that the power costs represent 86.8 per cent.; repairs and maintenance, 3.5 per cent.; miscellaneous supplies, 2 per cent.; labor and operation, 7.7 per cent. These percentages are given on the actual operating costs, not including overhead charges.

Our rolling mill superintendent is strongly of the opinion that the motor as applied to our mill is a decided success, as it is flexible in that it starts, stops and accellerates to the entire satisfaction of his rollers and that the tonnage produced is equal to all expectations. He states that the source of delays due to the reversing motor from an operating standpoint, is practically nothing and that he has never had any fear of trouble from this source, that is, no incidents have come up in his experience with this equipment to cause any anxiety when away from the mill, as the equipment is so simple and the results are so good. He states further that the motor installation is good from the tonnage point of view and that if any more mills were installed at our plant, he would certainly recommend similar equipment being installed.

There is one source of trouble and delay which we have, but it is not chargeable to the equipment in any way, that is, the delays due to interruption of power. All our mills are supplied from a central station over a transmission line some 40 miles in length and during the winter season we are subject to interruptions caused by storms and needle ice at the point where the power is generated, but notwithstanding these troubles, he would much prefer an electrically driven mill, such as we have, over any steam installation which he has ever seen.

ELECTRICALLY DRIVEN REVERSING ROLLING MILLS

Discussion by Addison H. Beale

General Superintendent, Mark Plant, Steel and Tube Company of America.

From an operating standpoint, the measure of merit, so far as electric drives are concerned, is one of performance. An opinion has been solicited as to the success of electric drives for reversing mills.

At the Mark Plant of The Steel & Tube Company of America, there is an installation of three separate electrically driven reversing mills which may be briefly described as follows:

35″ blooming mill, driven by a 15,000-H.P. maximum rated 2-unit reversing motor.

30″ plate mill, capable of rolling universal plates up to 42½″ in width and sheared plates to a maximum of 78″ in width. An 8000-H.P. maximum rated single-unit reversing motor drives this mill.

28″ billet mill, driven by a 5000-H.P. maximum rated single-unit reversing motor.

The above mentioned mills have been operating but a comparatively brief period. Each of the above electrical units was placed in service prior to the full completion of the mills which they were expected to drive. The operating conditions have not been entirely favorable and the full possibilities of the equipment have not yet been realized. The billet mill was placed in operation in September, 1917. The blooming mill and plate mill were both started in April, 1918. The blooming mill operated single turn for a total of 68 single 12-hour turns and operated 317 double turns to September 1st, 1919. The plate mill

operated first on single turn a total of 63 12-hour turns and a total to September 1st, 1919, of 335 double turns.

The product rolled from our blooming mill is one of slabs for the plate mill and blooms for the billet mill. The orders on this mill include a variety of sizes and the ingots used range from 14″ x 16″ x 72″ to 16″ x 38″ x 72″.

The greater quantity of product from this mill is that of slabs for the plate mill. This mill has rolled to September 1st, a total of 316,824 net tons. We have only had sufficient steel one month during this period to get any approximate idea of what the possibilities are on this mill. The production, however, has not been decreased in any way through failure of the drive.

Our plate mill operation has been devoted largely to universal plates. A small tonnage of sheared plates has been rolled successfully. The orders are varied on this mill, both in thickness and in width, the product being used principally for skelp plate for lap-weld pipe mills. This mill has rolled a total of 167,415 net tons from the time of its starting up to September 1st, 1919. We have had but one month since it was placed in operation when we had sufficient steel to give to the mill to demonstrate its possibilities; this was the month of October, 1918. In that month the mill rolled 17,400 tons in 54 turns, averaging 322 tons per turn. The largest single individual 12-hour turn production on this mill to date has been 494 gross tons.

The production on both the blooming mill and the plate mill has been restricted up to the present by the quantity of steel we have had to give them through our inability to provide a sufficient quantity of open-hearth and Bessemer products. The limitations of production on these two mills may best be appreciated by an inspection of the delay reports for six months of the current year.

The electrical delays on the blooming mill on the main drive totaled 6 hours, on the auxiliary drives, 14 hours 10 minutes. In this same period we had a total delay of

508 hours 15 minutes waiting on steel. The mechanical delays amounted to 43 hours 20 minutes.

The delays in the plate mill from January 1st to July 1st, 1919, on the main drive totaled 4 hours 35 minutes, auxiliary drives 44 hours 5 minutes. The mechanical delays were 37 hours 5 minutes. Waiting on steel, 317 hours 45 minutes.

Under the heading of ''auxiliary drives'' we have included all electrical delays due to cranes and charging machines. You will observe from the above that comparatively little delay can be attributed to the electric drive. These delays might be further minimized were they a limiting factor of production.

In the paper just read on ''Electrically Driven Reversing Rolling Mills,'' reliability, ease of operation, economy in operation and maintenance as advantages afforded by electric drives were commented upon. We believe that the figures we have just given speak well for the reliability of the electrical apparatus.

It is to be further noted that the transmission of power electrically from the power house to the mill is thoroughly reliable. We have yet to experience our first delay from this source.

As to the ease of operation, I do not hesitate to state that our reversing motors can be controlled accurately, easily and with an inexperienced operator. A single attendant performs the few duties required within the motor house on each mill. The operation of both of these mills is flexible in that the mill may be started or stopped on shorter notice than is possible with an engine installation.

In days like the present when skilled labor is scarce, the true value of these sets is in evidence. Full economy has not been realized in the matter of power consumption due to a somewhat intermittent operation as stated. The drives from an operating standpoint, however, are entirely satisfactory in every respect. The power consumed by the reversing motors varies with the rolling

schedule. An average figure that it would be safe to use would be approximately 31 K.W. hours per ton at the blooming mill and 53 K.W. hours per ton at the plate mill. This electrical power is the product of efficient turbine generators in the power house. Due to the diversity of power at the different mills the load at the power house and boiler house does not fluctuate excessively, so that the equipment at these points may be operated with good economy.

The maintenance of these electric drives is not an item of heavy expense. Every week-end the apparatus is cleaned by one attendant and at intervals the equipment is thoroughly inspected and overhauled. This does not require a crew of over four men for one day. The repairs and renewals upon our electrical apparatus to date have been of a comparatively light nature.

In conclusion I desire to state that it has been our experience that electrically driven reversing mills are effective and efficient producers and that they may be operated and maintained with comparative ease and with economy far beyond any reversing steam unit that I have had experience with.

President Gary: We come now to something you will be glad to listen to and have been waiting for, "The Open-Hearth Furnace and Processes," by Dr. Henry M. Howe, Bedford Hills, New York.

THE OPEN-HEARTH FURNACE AND PROCESSES

Henry M. Howe

Emeritus Professor of Metallurgy, Columbia University, New York

A few years ago you had a general paper on the blast furnace, which was followed by many papers, each dealing with some specific phase of blast furnace practice or construction. These collectively form the most comprehensive and probably the most valuable treatise ever written on this subject.

You propose a like treatment of the open-hearth furnace and processes. With the aid of Messrs. Walker and Gray, I have made an outline sketch of this subject. This I understand is to be followed by a series of papers of which Mr. Fry's contribution of today is the first, each treating some important feature of open-hearth construction or procedure.

First, taking up the furnace construction, we may ask our mechanical engineers whether they cannot design the tilting furnace so as to reduce the cost of its upkeep until it no longer is a serious consideration in deciding between the tilting and the stationary furnace. And we should discuss the real saving in time and the other advantages of tilting, and the conditions under which it is most useful.

The efficiency of the open-hearth furnace depends in large part on that of the regenerators regarded as heat filters. Our present regenerators seem very crude, having for instance about the same construction in their upper as in their lower parts, though the heat conditions differ so enormously from top to bottom. We may well ask whether the passages should not be larger above, where the gases are so greatly expanded, than below. Further, whether the bricks themselves may not be improved. They catch and emit the heat at their surfaces only, but store it in their interiors. Hence their surfaces

should be extensive and their material should transmit heat readily from surface to interior and back. This transfer calls for a dense, and perhaps even a semi-glazed state. A hard brick of great conductivity, even if too fusible for the upper part of the checkers, might well be used in the lower part. Again, the extent of surface might be increased, first by making the bricks very thin, and second by ribbing their sides with vertical ribs that would not catch the dust.

The efficiency of the furnace depends further on the accurate retention of the shape of certain parts; for instance, the ports and valves. It may be well to inquire carefully in what parts of the furnace the advantage of accurate retention of shape by means of water-cooling outweighs the loss of heat involved.

For moving the incoming and escaping gases, how does the profit from using fans compare with the cost of their installation and operation? Their use thus far is promising. I introduced them for both purposes in 1874.

We may ask what is the useful limit of size of the furnace itself, the limit where the disadvantages of irregularity of temperature and composition, and of excessively great units for soaking and rolling, outweigh the advantage of saving of fuel, labor, and installation per unit of product. This limiting size will be greater for quantity than for quality practice.

How should the pitch of the ports be related to the length of the furnace, to the kind of fuel, and to the stock? Flatter ports might be needed for charges rich in scrap, which have to be protected from oxidation during melting, than for molten pig iron which has to be oxidized vigorously.

How deep should the bath be at its deepest point, first so that it may work as fast as is consistent with thorough control; second, that we may gain the economy of large charges?

Turning now to the open-hearth process itself, we find many matters pressing for attention. Perhaps our great-

est need is to impress on our operators the extreme importance of controlling the composition of the slag, and especially of lowering its iron oxide. Precise maxima of iron oxide permissible for various processes and grades of steel should be established, and should be incorporated in all important contracts, quite as rigorously as the permissible sulphur and phosphorus contents of the steel itself.

The methods of lessening the quantity and harmfulness of inclusions need great improvement. Two essentials seem to be, first, ample time for the inclusions to rise by gravity in furnace, ladle, and perhaps mold; and second, fusibility of the oxides formed by the final deoxidizing additions, so that they may readily coalesce into particles large enough to rise rapidly. As a step towards this last, we should determine systematically the melting points of the combinations of oxides which it is practicable to form with these additions.

The quiet which results from thorough deoxidation of metal and slag may be held to have two simultaneous but opposite effects. It facilitates the rising of inclusions of given size, but it does not favor the coalescence of particles into masses large enough to rise fast, as rapid movement does. Witness churning for butter.

How far is the objection to the use of ore justified? We object reasonably to the use of rusty scrap because of the irregularity in the quantity of oxygen which this causes. In treating charges containing any considerable quantity of pig, much oxidation has to be done. Some very competent men would have this done wholly by the furnace gases and object to the use of ore, apparently on the ground that the resulting local over-oxidation is not readily overcome. They would have the oxidation superficial, brought about by the slag rather than by iron ore submerged in the metal itself. The evidence should be examined with care. We should not be led away by unsupported theories however plausible. Certainly the excellence of the acid open-hearth steel made with moderate

use of ore sets up something of a prima facie case for the ore process.

Should residual manganese be insisted on in making fine steel, and in general that on which human life depends? The demand for it rests on the belief that oxidation by means of manganese, acting as a carrier of oxygen, is beneficial in that it does not lead even to the temporary formation of iron oxide within the metal. This should be tested more thoroughly. If true, then the benefit of this treatment should cause some special merit in the product in the way of specially high combination, for instance of elastic limit and ductility or shock resistance, and the specifications might be amended so as to reject steels which lack it. I refer of course to steels for important purposes, failure in which would endanger life.

The relative merits of the basic and acid open-hearth processes should be established more firmly. The comparison should be made between the two as practiced under truly comparable conditions, for instance with nearly equal strength of deoxidizing conditions, and not between basic with 80 per cent. of pig iron and acid with only 25 per cent.

The advantages of the dominant pool of the Talbot process should be evaluated, so that they may be weighed against the disadvantage of having to make the steel in the ladle. Do we really gain enough time by leaving part of the charge in the furnace to overcome the objection to ladle steel-making, with its irregularity of composition?

We should satisfy ourselves that our American practice of using a low casting temperature for fine steel instead of the high temperature used in Continental Europe is right, and ask searchingly whether its advantages of giving freedom from surface cracks and of restraining both axial segregation and the coarseness of the columnar crystallization really outweigh its disadvantage of giving less opportunity for the inclusions to escape in the ladle.

The relative advantages of limestone and lime should

be weighed. Limestone is a cheaper material than ore for bringing on a boil, and with it we avoid introducing iron oxide into the molten metal as ore does, thus substituting superficial or slag oxidation for internal or submerged oxidation by the immersed ore. On the other hand it is derided as using the costly heat of the open-hearth to do the work of the cheap heat of the lime-kiln. How does the extra cost of this heat compare with the alleged advantages?

Turning now to the compound processes, including the duplex, triplex, Bertrand-Thiel, and others, we may divide each into a roughing and a finishing phase. The chief reason for their existence is to separate the silica formed by the oxidation of the silicon of the pig iron from at least the last part of the dephosphorization and desulphurization. Hence, they seem applicable primarily when an abundant pig iron needing dephosphorization or desulphurization is to be treated.

Among their additional advantages are first, their power of concentrating the phosphoric acid in a relatively small quantity of slag, which may be useful as a fertilizer even when the stock contains relatively little phosphorus; second, their use for making alloy steels directly and relatively cheaply from molten open-hearth or even Bessemer metal; and third, their improving the quality of molten-blown Bessemer metal by treating it directly and cheaply in the open-hearth or electric furnace, thus getting part of the cheapness and rapidity of the Bessemer process together with a quality at least approaching that of open-hearth steel.

These advantages are to be weighed against the inevitable serious loss of heat in transferring from one furnace to another, and the total loss of the initial manganese in the roughing phase, compelling us to replace it in the finishing phase if we are to have the benefit of residual manganese.

For the roughing phase the Bessemer converter, both acid and basic, the basic open-hearth, and the basic-lined

mixer are applicable; for the finishing phase, the basic open-hearth and the basic electric furnace.

The acid furnaces, electric and open-hearth, are hardly applicable here, because that which drives us to use a duplex process, all of which are relatively costly, is the need of having to remove both silicon and phosphorus, and the difficulty of doing it in a single process. Hence both phases of a duplex process are used for purification, the roughing phase for removing silicon and the finishing phase for removing phosphorus, a removal for which these acid processes are unfitted.

Here we should study the relative advantages of the three roughing furnaces. In using the Bessemer process for roughing we usually blow about two-thirds of the pig iron very full and the remaining third, or "kicker," only half way, to the end that the carbon left in the kicker, about 1.75 per cent., may in the finishing stage react vigorously on the iron oxide stored up in the full-blown metal, and bring on a boil. This full blowing wastes iron, time, and steam, so that the oxide which it generates is extremely expensive. We should satisfy ourselves whether its convenience justifies its use in place of iron ore or scale. Beyond this costliness, we may ask whether here, as in Bessemer practice in general, we do not sacrifice quality unduly to the convenience of having a clear signal for ending the blow, remembering how much better the Swedish Bessemer steel caught on the way down is said to be than our full-blown product.

We should ask further how far the damage to quality due to Bessemerizing is remedied in the finishing process, and how this finishing must be done to make this remedy effective. If this damage represents simply imperfect deoxidation of the iron and imperfect removal of inclusions, the remedy should be to hold the metal in the open-hearth or electric furnace so as to allow the inclusions to rise, and at a high temperature so that the carbon of the molten metal may react fully on the iron oxide present,

incidentally bringing about that quiet so favorable for the rising of the inclusions.

Of the two other roughing furnaces, the basic open-hearth seems to commend itself best when the pig iron contains relatively little silicon, and the mixer when it contains much, because of the greater trouble which silica gives in the open-hearth than in the mixer. We should seek clearer definition of the conditions appropriate to each of these two furnaces, and should ask what advantages the open-hearth has over the mixer to compensate for its higher operating cost, due to its smaller scale of working and its more intricate construction.

Again we should ask how far it may be possible to reduce the disadvantage of the Bessemer, its loss of iron, while retaining its advantage of rapidity and cheapness, and thus to invade with it the field now occupied by the basic open-hearth and mixer as roughing tools.

In the triplex process, for pig iron of moderate phosphorus content, we set between the roughing or desiliconizing phase and the finishing or fully dephosphorizing one, an intermediate phosphoric-slag making phase. Here the quantity of lime present in the slag is enough to bring about the removal of the greater part of the phosphorus, and yet not great enough to complete the dephosphorization, because a quantity of lime sufficient for this would so dilute the small quantity of phosphorus present that the resultant slag would be too poor in phosphoric acid to be useful as a fertilizer. We should try to learn the limiting conditions, especially as to the phosphorus content of the pig iron, under which this interesting process is profitable.

VICE-PRESIDENT KING: Judge Gary has asked me to relieve him as Chairman. I feel that I will be a very poor substitute and would ask that you bear with me with what patience you may.

The next paper, "Temperature Measurements in Steel Furnaces," is by Mr. G. K. Burgess, Chief of the Division of Metallurgy, Bureau of Standards, Washington, D. C.

TEMPERATURE MEASUREMENTS IN STEEL FURNACES

George K. Burgess
Chief, Division of Metallurgy, Bureau of Standards, Washington, D. C.

For several years past, the Bureau of Standards has been actively interested in some of the fundamental problems related to the steel industry, especially subjects of a scientific or technical nature. Among those with which I personally have been engaged, is the question of temperature measurement as applied to the various stages of steel manufacture. The particular phase of this subject, that of the measurement, control and interpretation of the temperatures of the masses of steel during its manufacture, and while the metal is still liquid, is, perhaps, the most difficult temperature domain to conquer, as it is likewise the most important from the economic point of view.

May we not state as an axiom that in a basic industry, if there is a factor, such as temperature of the operations or materials, which is generally felt to play a capital role, limiting in an as yet undetermined way, the quality, output and cost of product; then, in such cases, all reasonable effort should be devoted to ascertaining the effects of the factor in question.

That every steel maker is convinced of the importance of adequately defining quantitatively the role of temperature in the various stages of steel manufacture, I think, would be readily conceded; but is it not also true that no steel manufacturer can state for liquid steel, other than in vague terms if at all, the relation of temperature at each stage of the process of melting, refining and casting, to any of the other factors influencing his product?

There have been a number of papers published lately,

particularly by the Iron and Steel Institute of Great Britain, treating of the processes of steel manufacture, and in most, if not all of them, particular emphasis is placed on the role of temperature; but in none of them, apparently, does there appear, for the stages of the process while the steel is still within the furnace, statements of the relations of temperature to other factors backed up by satisfactory, quantitative measurements of temperature. This situation exists in spite of the fact that for many years there have been available pyrometric instruments adequate for use in the steel industry. The reason for this anomalous condition appears to lie largely in the fact that more than a pyrometer is needed.

As to the pyrometer, it is of interest to note that the demand for an instrument to measure temperatures of liquid steel came from the steel industry itself; and at the time, in 1892, when Sir Robert Hadfield requested M. LeChatelier to devise a suitable instrument, there was no existing type of pyrometer adapted to this purpose. The genius of LeChatelier, and the skill of the French optical firm, Pellin, produced the LeChatelier pyrometer, not to be confused with the thermoelectric instrument, also known as the LeChatelier pyrometer.

It was reserved to an American, E. F. Morse, to invent, in 1902, the most convenient type of pyrometer for use in measuring the temperatures of liquid steel and other incandescent and inaccessible objects; this pyrometer has since been simplified and improved by others. It is again not without interest to note that the steel industry itself furnished the basis for this invention, which was an improvement of a method invented by Messrs. Taylor and White for use in controlling the temperature of certain hardening baths at the Bethlehem Steel Company's plant.

In the portable form with tripod, the type I personally prefer, or in that manufactured by Leeds and Northrup, which is generally used, in which no tripod is required, the brightness of a small incandescent lamp at the

focus of a telescope is matched in brightness against the incandescent background of the liquid steel or other hot object. The electric current taken by the lamp gives a measure of its temperature and thus also of the steel if certain very important conditions are also fulfilled.

The consideration of these all important accessory conditions brings us to a phase of the subject, in part illustrated by what has gone before, but which may, perhaps, best be emphasized here; namely, for the solution of problems of this kind, there is generally required the co-operation of some three types of individuals, the steel maker who best knows his problem; the scientific man, or, if you prefer, the research laboratory, who can bring the application of abstract principles and methods of measurement to bear on the problem; and last, the instrument maker who can put in concrete and sufficiently robust form the ideas of the scientific man that best meet the needs of practice.

At the remarkable symposium on pyrometry held in Chicago last month under the auspices of the American Institute of Mining and Metallurgical Engineers there were papers relating to steel manufacture by these three types of men. Such an interchange of viewpoint and experience makes for progress. It was made evident by this symposium, however, that although there have been developed satisfactory instruments for measuring temperature in open-hearth and electric furnaces and of liquid steel streams; and there have been made sufficiently exact determinations of the underlying physical facts and phenomena on which such temperature measurements are based; and also there has been accumulated a considerable mass of experimental data relating to furnace operations by various observers; and above all, there has been unquestionably established a most splendid spirit of confidence and co-operation among the three types of men mentioned above; nevertheless, it is only fair to state there yet remains to be solved the essential kernel of the problem, namely, the actual, quantitative relations exist-

ing between temperature and the other factors relating to steel manufacture.

As illustration of the role played by the research laboratory in this problem of temperatures of liquid steel, let us take the determination of the corrections to be applied to the optical pyrometer readings to give true temperatures. The need of such correction arises from the well-known fact that the intensity of total and also of monochromatic radiation of any substance, not enclosed within a furnace uniformly heated, depends not alone upon its temperature but also upon the nature and character of the radiating surface. It then becomes necessary in the case of liquid iron, steel, oxides, and slags, for example, to find their emissivity or specific radiation for the colored light used with the pyrometer. This can best be done in the research laboratory and not in the steel plant. This fact needs emphasizing as it has sometimes been said, the research laboratory of a steel plant should be the steel plant itself. I believe it will be found, as in this instance, that the plant itself does not, in general, provide the facilities and material adequate for the determination of fundamental constants and properties.

Thus, we spent considerable time in various steel plants trying to determine the radiation characteristics of liquid steel but with unsatisfactory results. The actual determinations were made in the laboratory with an instrument we have devised which is identical in principle with the optical pyrometer above mentioned except that it was a microscope instead of a telescope, and the masses of steel operated upon, instead of being 50 tons or more, were of the order of a few thousandths of a milligram. With the micropyrometer, as we call it, we were able to show that the emissivity or specific radiation of pure iron is 0.37 with light of wave length, $\lambda = 0.65\ \mu$ (i.e., for red light used with the pyrometer, a free surface of iron radiates only 37% of the same light from a furnace at the same temperature as the iron); furthermore, this quantity ($e=0.37$) remains constant over the

whole temperature range of steel manufacture and is not altered by the presence of any of the elements which may be present in steel and iron, and is also nearly identical with the emissivity of nickel and even, as very recent measurements show, of monel metal and other alloys of iron or nickel so long as they show no change in color caused by alloying. Similar measurements were made for iron oxides in liquid and solid states and of slags. It was then a simple matter to construct correction tables for the pyrometer when sighted on any of these substances.*

As there is a mass of data which has been gathered on measurements of steel temperatures by the ever increasing number of observers, it is not my intention to go into detail here. They are available or referred to in the papers of the Chicago symposium. It may, nevertheless, be well to summarize here the present state of the subject.

The Pyrometer Committee of the National Research Council, among others, have made an extended survey of the possibilities of various methods of measurement of liquid streams of iron, steel and slag and of temperatures in open-hearth and electric furnaces.

The question of measuring accurately, most conveniently, and practically instantaneously, or to better than 5° at 1500°C. (2732°F.) in intervals of 5 to 10 seconds, the temperature of running streams of liquid steel, as in tapping a furnace or teeming ingots, may be said to have been solved some time ago by the use of the above described optical pyrometer of the modified Morse type, to the readings of which corrections are to be applied based on $e = 0.40$ for $\lambda = 0.65\ \mu$ when sighting on iron or steel with similar corrections for liquid iron oxide ($e=0.53$) and slags ($e=0.65$ or thereabouts depending somewhat on the nature of the slag). This does not mean that other pyrometers cannot be used successfully for this purpose,

*In steel manufacturing practice it was found advisable to adopt the value 0.40 rather than 0.37 for iron and steel and the correction tables are based on the $e=0.40$ for $\lambda=0.65\ \mu$, for reasons explained in the Bureau of Standards Technologic Paper 91, published 1917.

for they have been, including other types of optical pyrometers and various total radiation instruments.

It has been demonstrated also that the arch or dome of an open-hearth furnace may be watched and its temperature controlled by the same pyrometer, although here no corrections appear to be necessary to the observed temperatures.

Similarly, the temperature of the surface of the slag in an electric or open-hearth furnace may be observed through peep holes with doors shut if care is taken to avoid flames and smoke; and the progress of the heat as related to slag temperatures may be followed with considerable accuracy at least for open-hearth furnaces.

The most difficult and most important problem is to determine, for any instant of time and condition of bath, the temperature of the metal bath itself. There is, perhaps, some comfort in appreciating that, in general, this difficulty is offset in part by the fact of non-uniformity of temperature within the metal unless the bath is well and frequently stirred. These differences within the bath, as have been shown from a series of observations of tapping temperatures, may reach, under certain methods of operating, 200° F. or more and are evidently within the control of the melter.

Considering the apparently crude methods in use, it is a source of wonder to anyone who has had occasion to check the temperatures of steel, as cast, to note the marvelous uniformity attained from one heat to another by the furnace men. For example, the method of timing the appearance of crust in the chill test as often used appears to have no necessary relation to the bath temperature; nevertheless, this remarkable uniformity in casting temperatures extends over the whole steel industry.

The Pyrometer Committee, above mentioned, made a series of trials of an improved form of the chill test, devised by Mr. Drinker, and were reluctantly forced to the conclusion that reliable estimates of bath temperatures cannot be obtained by this method. All methods, which

depend on lifting out metal from the furnace in a spoon, are subject to so many sources of error and require such rigid exactness of manipulation as to be unsuitable for ordinary practice and of doubtful reliability even when extraordinary care is exercised, although there have undoubtedly been made excellent individual observations by such methods.

An elaborate series of experiments were carried out by the Committee with various refractory tubes thrust into the metal bath; but, with the exception of the single substance, Acheson graphite, no material was found satisfactory. In this procedure the optical pyrometer is sighted down the tube on the closed end of graphite immersed in the bath to the desired depth. More surveys should be made by this method using graphite tubes. Pieces of graphite or graphite tubes may also be plunged into and held beneath the surface of the bath in electric and open-hearth furnaces and then allowed to come to the surface or removed from the furnace entirely, and the temperature of the metal at any depth may then be estimated quite accurately in either case from observations taken with the optical pyrometer of the graphite temperatures. No corrections have to be applied to the instrument sighted on graphite, and this graphite has the further advantage that slag does not stick to it.

The question of following electric furnace temperatures is complicated by the presence of the electrodes, but the practice of changing slags gives opportunity for intermittent temperature observations of a satisfactory nature by various methods as shown by Mr. Bash in a paper presented at the Chicago symposium. The technique of electric furnace temperatures, however, needs considerable additional study. From a comparison of casting temperatures of several electric and open-hearth furnaces in normal operation, Mr. Bash concludes that electric furnaces are not tapped at higher temperatures than are open-hearth furnaces, as is often held.

It would appear that heretofore most of the determina-

tions of furnace temperatures have been made by representatives of the research laboratory or instrument maker, and nearly all the published observations were so taken, although there is undoubtedly in existence considerable data and experience accumulated by steel makers themselves. It is evident that discontinuous observations taken somewhat casually by outside parties, although they may serve excellently for demonstration purposes, can nevertheless by no means replace the continuously carried out observations made by representatives of the steel maker himself over long periods of time and under the incessantly changing conditions of practice. In this way alone can the problems of temperature conditions, control and interpretation be solved.

There has been furnished the steel maker for this task, a simple, accurate and convenient pyrometer; the technique surrounding the taking of steel furnace temperatures has been sufficiently, if not definitely, worked out; and there have been determined all the fundamental physical constants necessary for transposing the observational readings into actual temperatures. The steel maker himself will have to solve the rest of the problem.

Vice-President King: The next paper on the program is "The Manufacture of Ingots for Locomotive Tires and Rolled Wheels," by Mr. Lawford H. Fry of the Standard Steel Works Company, Burnham, Pa.

THE MANUFACTURE OF INGOTS FOR LOCOMOTIVE TIRES AND ROLLED WHEELS

LAWFORD H. FRY
Standard Steel Works Company, Burnham, Pa.

This paper describes methods used in this country in manufacturing ingots for steel tires and rolled steel wheels for railroad service. No attempt is made to study the details of the steel making, as that is properly considered under open-hearth practice and processes. Similarly, the forging and rolling processes subsequently applied to the ingots are only considered here in so far as they affect the design of the ingot.

Railroad tires and wheels are bracketed together as being made from the same class of steel, because for both, the processes of manufacture, though differing in detail, require a ring of sound steel as their starting point.

CLASS OF STEEL USED.

The steel commonly used is shown by the following table, compiled from the specifications of the American Society for Testing Materials.

Product	Carbon, per cent.	Manganese, per cent.	Phosphorus, per cent.	Sulphur, per cent.	Silicon, per cent.
Tires, Class A	0.50 to 0.70	not over 0.75	not over 0.05	not over 0.05	0.15 to 0.35
Tires, Class B	0.60 to 0.80	"	"	"	"
Tires, Class C	0.70 to 0.85	"	"	"	"
Rolled Wheels (Acid)	0.60 to 0.80	0.55 to 0.80	"	"	"
Rolled Wheels (Basic)	0.65 to 0.85	"	"	"	0.10 to 0.30

Class A tires are usually used for the large diameter driving tires for passenger locomotives; Class B tires, for drivers for freight locomotives, for locomotive truck and tender wheels, and for car wheels; Class C tires, for driving tires for switching service. The large majority of tires are made from acid open-hearth steel, while rolled wheels are made from both basic and acid open-hearth steel. In view of the exacting nature of the

service, clean dense steel is essential, but with care in the steel making good results can be obtained with acid or basic open-hearth, or with electric steel.

Processes of Tire and Wheel Manufacture.

Without going into details it is convenient in a discussion of the ingots, to have before us an outline of the processes to which they are to be subjected. This is given in Fig. 1.

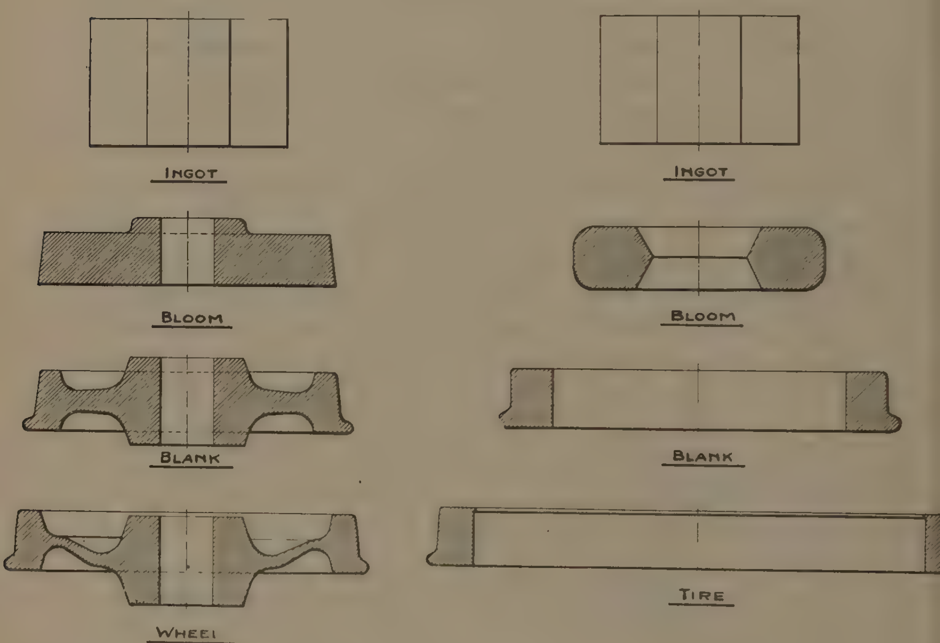


Figure 1—Processes of Tire and Wheel Manufacture

An ingot or a portion of an ingot of a weight to make a tire or wheel is heated and compressed in the direction of its longitudinal axis and a hole is punched through the center. The resultant piece, which is commonly known as a "bloom," is generally similar for tires or wheels except that for wheels the hole is smaller in diameter and in some cases the hub is partly formed in this operation.

In the succeeding operation the "bloom" is formed

into a "blank" in which the shape of the finished product is roughly apparent. A subsequent rolling operation completes the manufacture of the tire or wheel.

The details of the various forging and rolling processes lie outside the scope of the present paper, but the foregoing outline is given to show that, as a necessary part of the manufacture of tires or rolled wheels, the central core of the ingot is punched out and discarded. This point is of importance in connection with the use of individual ingots dealt with below.

Types of Tire and Wheel Ingots.

Coming to a consideration of the ingots, the first step is a classification into multiple ingots and individual ingots. The difference lies in the fact that the individual ingot is cast of a size to make a single tire or wheel, while a multiple ingot is sliced, at right angles to its long axis, into a number of blocks each of which is formed into a tire or wheel. This slicing was formerly done by heating the ingot and shearing under a press or hammer, but is now generally carried out cold on a slicing lathe with multiple tools.

Metallurgically considered the two types of ingots are differentiated by the principles involved in the elimination of piping and segregation. Multiple ingots are designed to concentrate these defects in the upper quarter of the ingot which is discarded after slicing the lower portion into blocks, while individual ingots are designed to eliminate piping almost entirely, to reduce segregation to a minimum, and to place these defects so that they are completely removed by the punching operation in the first process of manufacture.

To complete the record, it should be noted that in one process of wheel manufacture the "bloom" is formed, not directly from an ingot, but from a bar 12 or 14 inches in diameter rolled from an ingot and sheared hot into slugs of the proper weight. The ingots used in this process are rectangular in cross section, measuring about

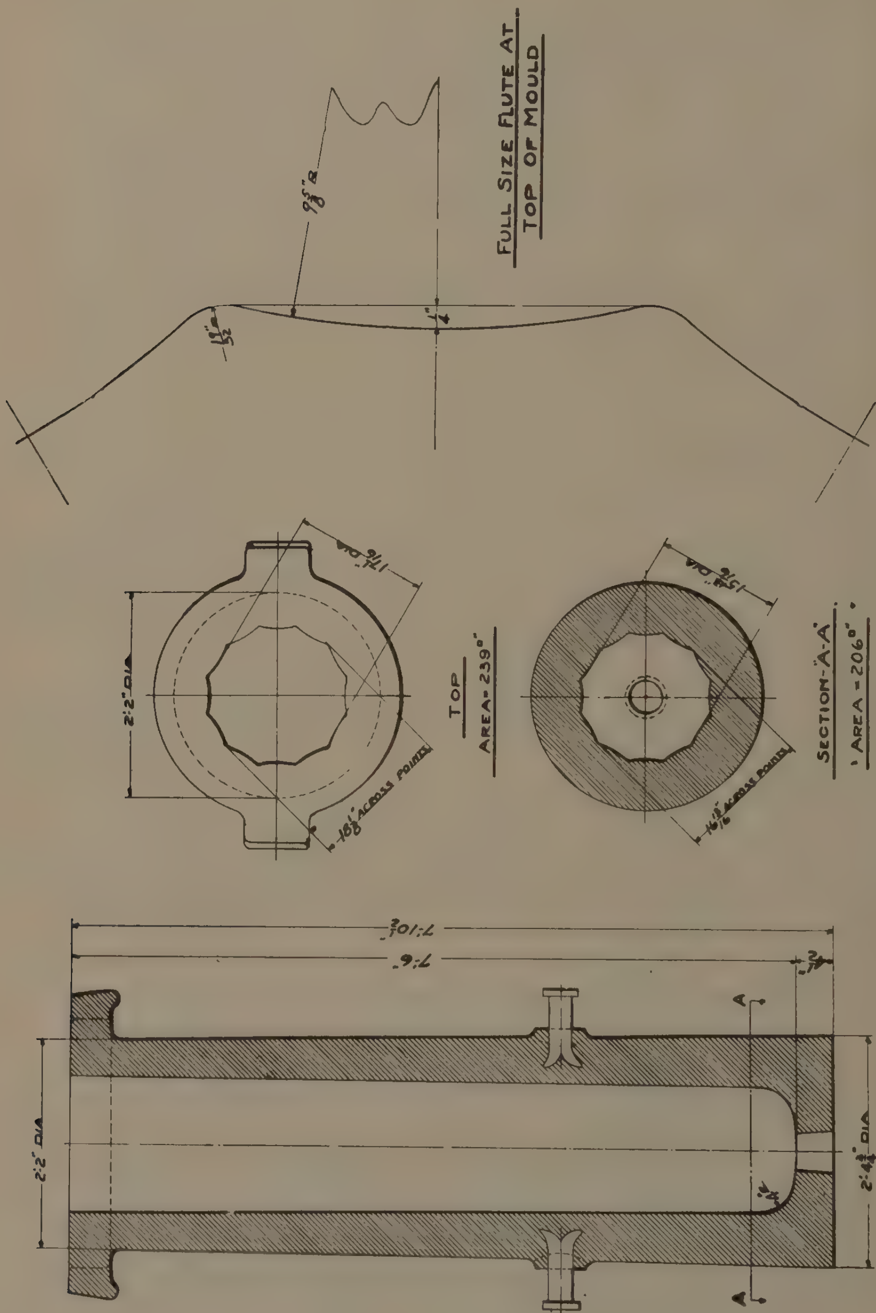


Figure 2—Ingot Mold for Multiple Ingots

20 x 27 inches. Such ingots are related to the other ingots used for rolled bars, rather than to tire and wheel ingots proper, and are therefore not further considered in this paper.

Multiple Ingots.

As it is more widely used and better known, the multiple type of ingot is examined first. Multiple ingots

Figure 3—Multiple Ingot showing Method of Cutting and Discard

usually have an eight or twelve-sided cross section with concave sides. The dimensions of a series of 12-sided ingots used by one tire manufacturer are given in Table I., while the mold dimensions used by another tire and wheel manufacturer are shown in Fig. 2. The mold in Fig. 2 has twelve slightly concave sides, and with a nominal diameter of 17 inches produces an ingot about 94

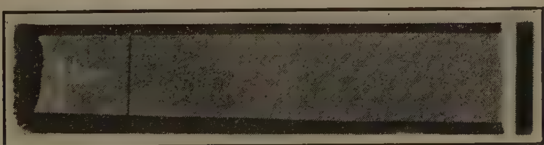


Figure 4—Section through Longitudinal Axis of Ingot

inches long, weighing about 64 pounds per inch of length. Ingots of this type are made with diameters of from 10 to 30 inches, according to the weight of the piece to be made. Both makers, whose practice is illustrated in Fig. 2 and Table I., use acid open-hearth steel, bottom poured, with hot tops on the ingots. An earlier form of ingot is illustrated in Fig. 3. This is a bottom poured, flat sided, octagon ingot which has been sliced hot into blocks A, B

and C, each of which will make one tire. The unlettered section is the discard necessary to eliminate piping and segregation. The necessity for this discard is illustrated by Fig. 4, which shows a section through the longitudinal axis of a similar ingot. The horizontal line shows the

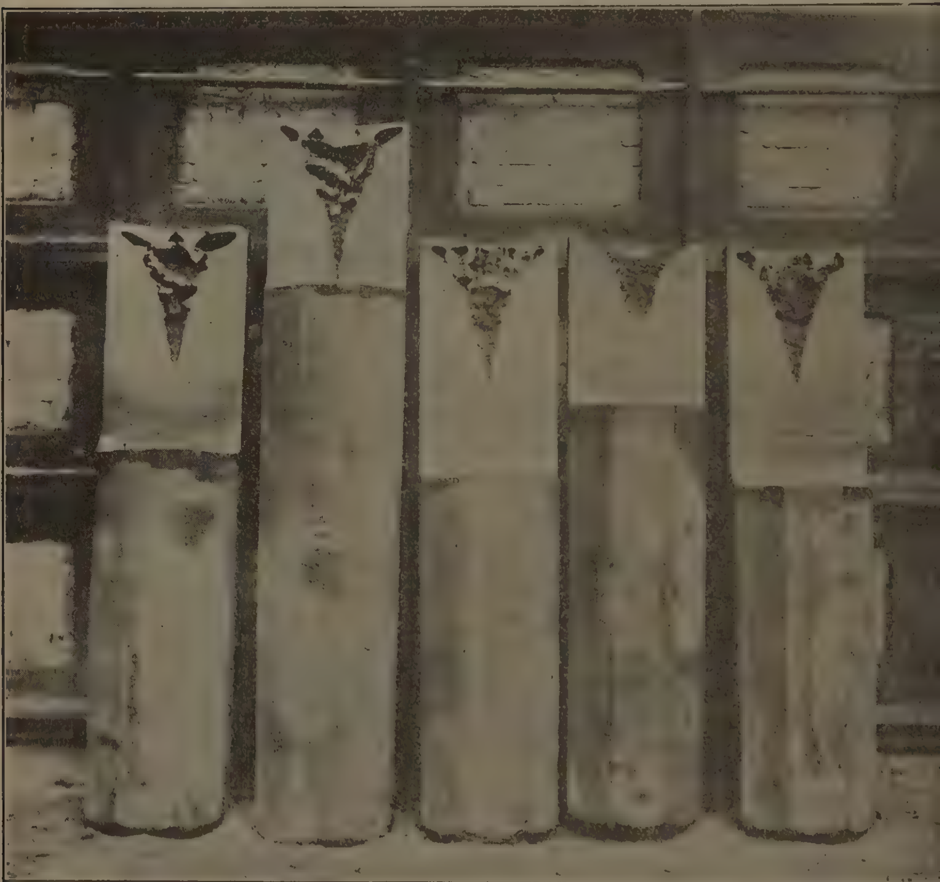


Figure 5—Ingots cast without Hot Top

discard necessary to secure reasonably sound steel. In Figs. 3 and 4 the discard amounts to approximately 20 per cent. of the ingot weight. The amount of discard necessary can be reduced by using some form of hot top by which the head of the ingot is kept hot and fluid until

the greater part of the shrinkage in the body has taken place. This is shown by the two series of ingots in Figs. 5 and 6. In each series the upper part of the ingots has been sectioned on the longitudinal axis. The ingots in Fig. 5, cast without hot-top, have a pipe extending throughout the upper 20 to 25 per cent. of their length.

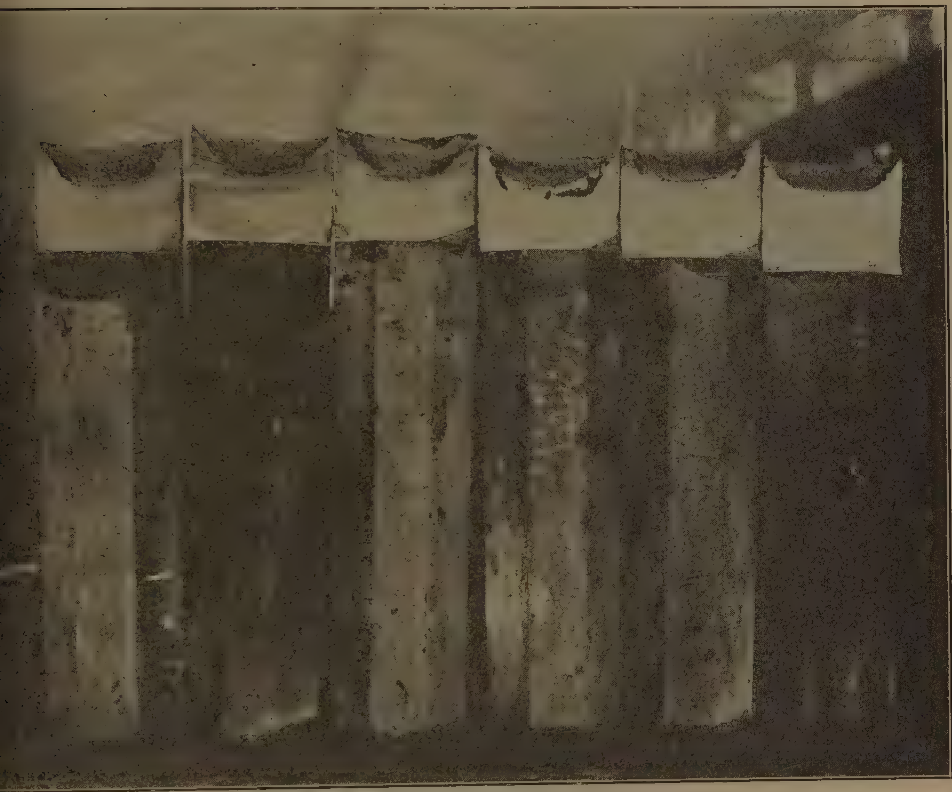


Figure 6—Ingots cast with Hot Top

The ingots in Fig. 6 had their upper portions protected from contact with the iron mold by a heat insulating jacket and in addition a layer of carbonaceous material was applied to the ingot top immediately after pouring. Piping has been eliminated and a discard of 10 per cent. would be sufficient to remove all segregation and to leave only sound usable steel. The ingots in Fig. 6 are an

experimental series in which the heat insulation was applied in a recess in the top of the mold so as to keep the diameter uniform throughout the length of the ingot. In practice it is more convenient to keep the mold of uniform diameter and to insert a brick or sand head to provide insulation or to make up a sand head in a cast iron casing placed on the top of the mold.

TABLE I.—SHOWING DIMENSIONS OF 12-SIDED FLUTED TIRE INGOTS USED BY A TIRE MANUFACTURER.

			Dimensions of Ingot Body				Ingot Top		
			Diameters					Diameters	
Nominal Diameter	Approx. Weight	Length	At Top		At Bottom		Length	Top	Base
			Across Hollows	Across Points	Across Hollows	Across Points			
Inches	Lb.	In.	In.	In.	In.	In.	In.	In.	In.
16	5400	84.7	16.5	18.6	15.3	17.1	10	17	15
18	6800	84.7	18.5	20.4	17.3	19.3	10	19	17
20	8400	84.7	20.5	22.7	19.3	21.6	10	21	19
24	11000	84.7	23.5	25.7	21.9	24.5	10	25	23

Individual Ingots.

While the use of multiple ingots is fairly well generalized, the use in America of the individual ingot for tires and wheels is confined at present to the Standard Steel Works Co. A representative ingot mold for this type is shown in Fig. 7. It is octagonal in section and is currently made with diameters 12, 14, 16, 18, 20 and 22 inches across the flats. The heights poured in each diameter range from about 60 to 100 per cent. of the diameter. This with the six above mentioned diameters gives weights ranging from 250 to 1900 pounds, each ingot being of a weight to produce a single tire or wheel. Fig. 8 shows longitudinal sections of two typical 16″ octagonal individual ingots.

The distinguishing feature of the individual ingot is the fact that it does away with all top cropping, the only discard necessary being the central core removed in punching the bloom. This is less than three per cent. of the weight of the ingot.*

*In comparing the yield of individual and multiple ingots it must be remembered that this punching loss occurs in both types, so that, while in the individual ingot the total loss is the furnace loss plus the three per cent. punching loss, in the multiple ingot it is furnace loss plus three per cent. punching loss, plus ten or twenty per cent. top discard, plus cutting loss, plus a possible bottom discard.

This result is obtained by eliminating piping and concentrating segregation. It will be seen in Fig. 8 that the steel is practically solid throughout. This solidity is the result of maintaining the top of the ingot fluid so that it can follow all shrinkage as it takes place and prevent

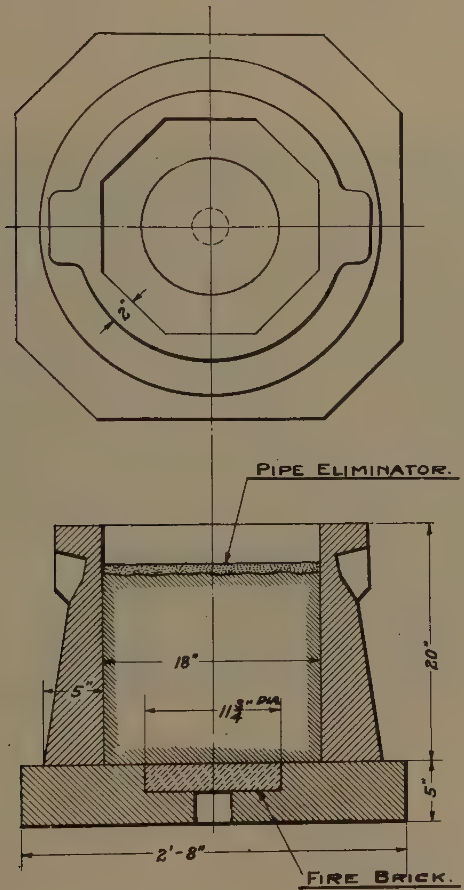


Figure 7—Ingot Mold for Individual Ingots

the formation of cavities. To secure satisfactory ingots it has been found necessary to have well made, dead melted steel, to have a properly designed mold, and to apply a suitable carbonaceous material to the top of the steel as soon as it is poured.

A short history of the development of the present form of the individual ingot in America will show the difficulties inherent in the process and the methods used to overcome them. The use of individual ingots goes back to the earliest days of the manufacture of tires in this country. About twenty-five or thirty years ago difficulties with the individual ingots then in use led to the introduction of multiple ingots and by the year 1900

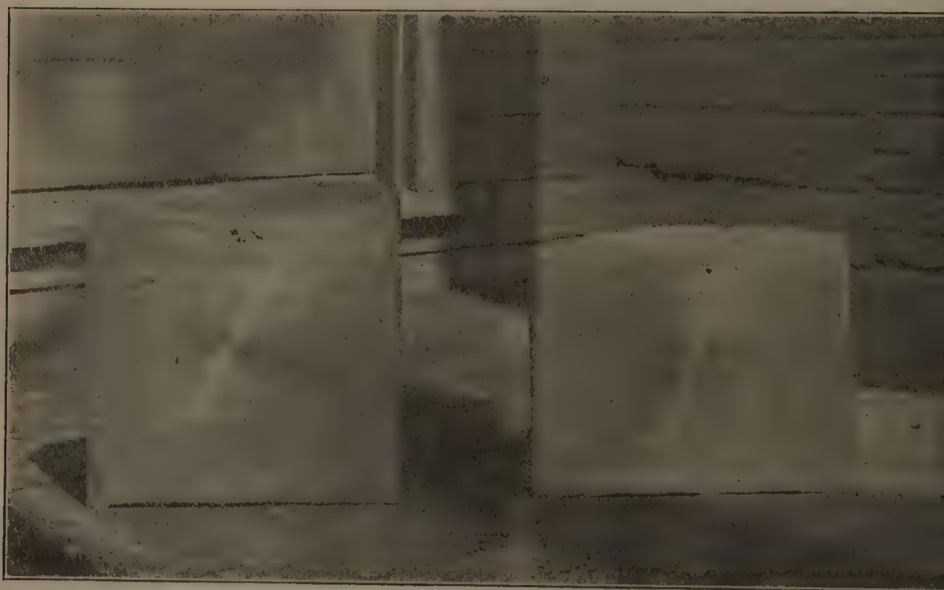


Figure 8—Longitudinal Sections of Two Typical Individual Ingots

individual ingots, though continuing to be used in Europe, had been abandoned in America.

In the year 1908 the attention of Mr. S. M. Vauclain was called to the economy in steel possible with the individual ingot. The problem of redesigning the individual ingot so as to eliminate its former defects and at the same time retain its economies was referred to and successfully solved by Mr. J. P. Sykes, then superintendent of the Standard Steel Works Company. Samples of European ingots were obtained and experiments started.

Sections of the early ingots are shown in Fig. 9. Fig. 9A is the original European ingot, which was bottom poured in a closed mold. It shows a heavily honeycombed interior, and although satisfactory tires have been produced from such ingots in Europe, they were not adapted to American practice. A modified form of this design is shown in Fig. 9B. This, though better, is still honeycombed. Another form, Fig. 9C, is hardly so promising. Fig. 9D poured from the top in an open mold marks an advance, but it is marred by the large pipe cavity due to the top having frozen too rapidly. The problem of eliminating the pipe by keeping the top of the ingot fluid

Figure 9—Sections of Early Forms of Individual Ingots

was finally solved by applying powdered coke or graphite. The form of ingot then adopted is illustrated in Fig. 10. The horizontal cross section is circular and the vertical section is a truncated cone on a short cylinder. The shop name for these ingots was "chocolate drops." The ingots in Fig. 10 have been parted by sawing from two opposite sides and fracturing and the picture is not entirely clear as to the extent of the pipe. The ingot marked B5 has a rather larger pipe than is desirable, while the two ingots marked B2 have narrow pipes which would be removed in punching. Ingots of this type proved so satisfactory and so economical that the use of the multiple ingots for tires and wheels was abandoned by the Standard Steel Works Company.

Since the introduction of the individual ingot further

improvements in its design and manufacture have been made. The circular cone section has been replaced by an octagon cross section with straight vertical sides as in Fig. 8 and the material now used to keep the top hot is a special compound described below. Many investigations of individual octagon ingots made with this compound have shown that the freedom from piping illustrated in Fig. 8 is typical and can be secured in regular practice. Segregation is also confined within satisfactory limits. The results of a chemical survey shown in Fig.

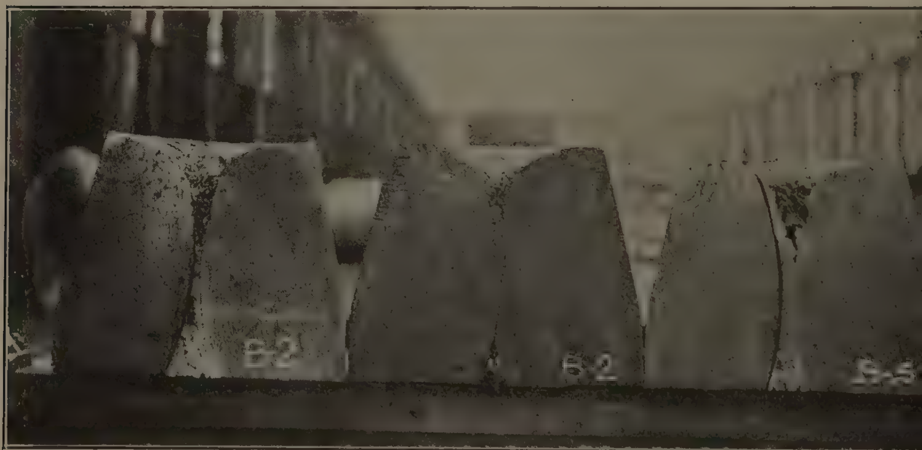


Figure 10—Late Form of Individual Ingot

11 are representative. Complete analyses were made at the points indicated. The silicon and manganese showed no appreciable variation at any of the points. Carbon, phosphorus and sulphur were distributed as shown. It will be seen that no serious segregation is found outside a narrow triangle having its base at the top surface of the ingot and its apex on the longitudinal axis. This triangle corresponds, in the full ingot, to a cone which is removed in punching. Surveys of completed tires and wheels confirm these conclusions as to the removal of injurious segregation during manufacture.

Too much emphasis cannot be laid on the fact, already

mentioned, that to secure individual pipeless ingots of uniform composition three conditions are essential:

1.—Well made dead melted steel.
2.—Correct ingot mold proportions.
3.—Proper carbonaceous material for the ingot top.

These are sufficiently important to be examined separately and in detail.

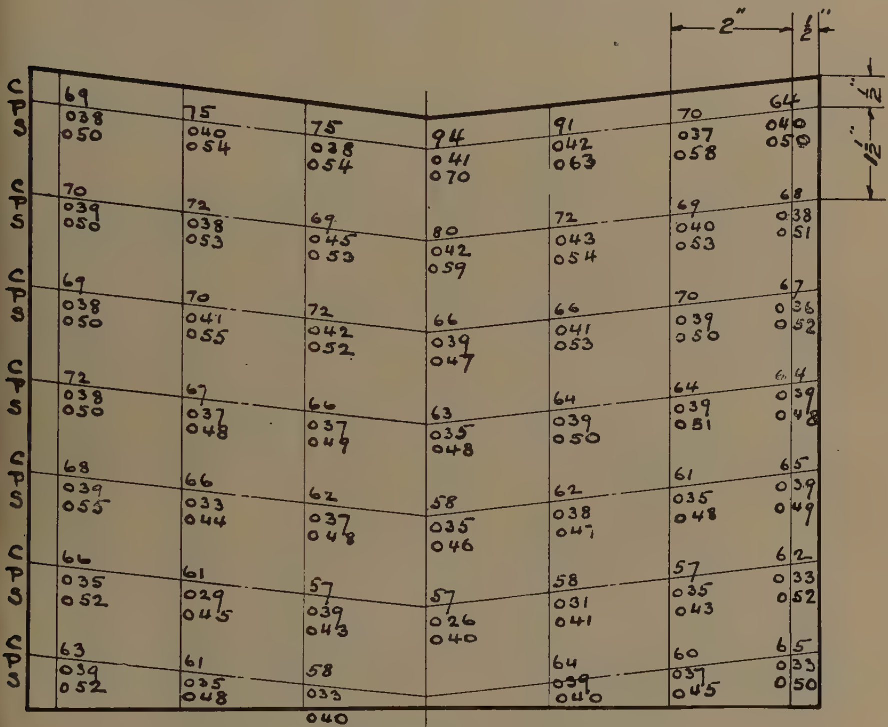


Figure 11—Chemical Survey of Individual Ingot

Steel.

Individual ingots have been made with both acid and basic open-hearth steel, and could be made with electric steel if occasion arose. This is not equivalent, however, to saying that any steel will do. It is essential that the steel be well made, properly deoxidized and dead melted so that it will lie quietly in the molds without any

tendency to "wildness" or boiling. That is to say, the evolution of gas by the steel in the mold must be reduced to the minimum possible. The ingots should be carefully inspected for piping, rough tops or other defects. In particular any ingots showing signs of having boiled or risen in the mold should be rejected, as they will be honeycombed to a dangerous extent. If the open-hearth practice is kept up to the mark and care is taken with the pit practice, individual ingots can be made to pass the necessarily severe inspection with rejections well under one per cent.

Ingot Mold Design.

A satisfactory mold is illustrated in Fig. 7. It is important to have the walls thick at the base and thin at the top so that the chill effect is greater at the base, and the cooling progresses from the bottom to the top of the ingot. It is also essential that the height of the ingot should be in proper proportion to the diameter. If the ingot is too flat the segregated area will be wide compared with the punch diameter, while too high an ingot will tend to give excessive piping. It has been found desirable to keep the height between 60 and 100 per cent. of the diameter of the octagon.

Carbonaceous Material.

A satisfactory material has only been arrived at by a continuous process of trial and elimination. In the manufacture of multiple ingots with hot tops, it has long been a common practice to add powdered coke, charcoal or coal to the upper surface, and with these ingots, where considerable discard is made to reject recarburized metal, satisfactory results can be obtained with such materials. In the case of individual ingots, however, the problem is more difficult. The work required of the material is quite complex and the difficulties encountered with other materials have been such as to narrow the choice to the compound referred to above, which is known as pipe eliminator. The material used must keep the ingot top hot

and at the same time leave it with a smooth uniform surface; it must also prevent a recarburization of the surface. It has been found that to give these results the pipe eliminator must be finely divided and must carry a small amount of volatile matter so that it will ignite rapidly on application to the steel. There must also be present sufficient inert material or ash, which, after ignition, forms a blanket between steel and eliminator preventing undue absorption of carbon by the steel. It is further necessary to have a considerable proportion of slow burning fixed carbon so that the top is maintained hot during the solidification of the ingot.

Open Hearth Pit Practice.

When the pouring conditions are considered it is obvious that there is a good deal of difference between the "set-up" for bottom-poured multiple ingots weighing from 5,000 to 12,000 pounds and individual top-poured ingots with an average weight of about 900 pounds. The grouping of the long bottom-poured ingots is well known and requires no description, but the arrangement of the open-hearth pit floor adopted by the Standard Steel Works Company may be of interest. This is shown in Fig. 12. The ladle of 50 tons capacity is carried on a gantry so as to just clear the ingot molds, which are set up on five lines of base plates. The height is kept as low as possible to avoid splash. The ladle has two stoppers spaced to correspond to the base plates, so that with two operators a brace of ingots can be poured at once. The sequence of operations is: the base plates are carefully inspected and any defective bottom bricks repaired or replaced; molds of the size ordered are set up and a chalk mark made on the inside of each to show the height to which the steel is to be poured to give the weight required; the steel is poured to the chalk mark, and a scoopful of pipe eliminator added; when the ingots have set, the molds are lifted off and as soon as the ingots are cold enough to be magnetic, they are transferred by mag-

net to the classifying shed. Accuracy in the weights of the ingots is essential and with an average weight of about

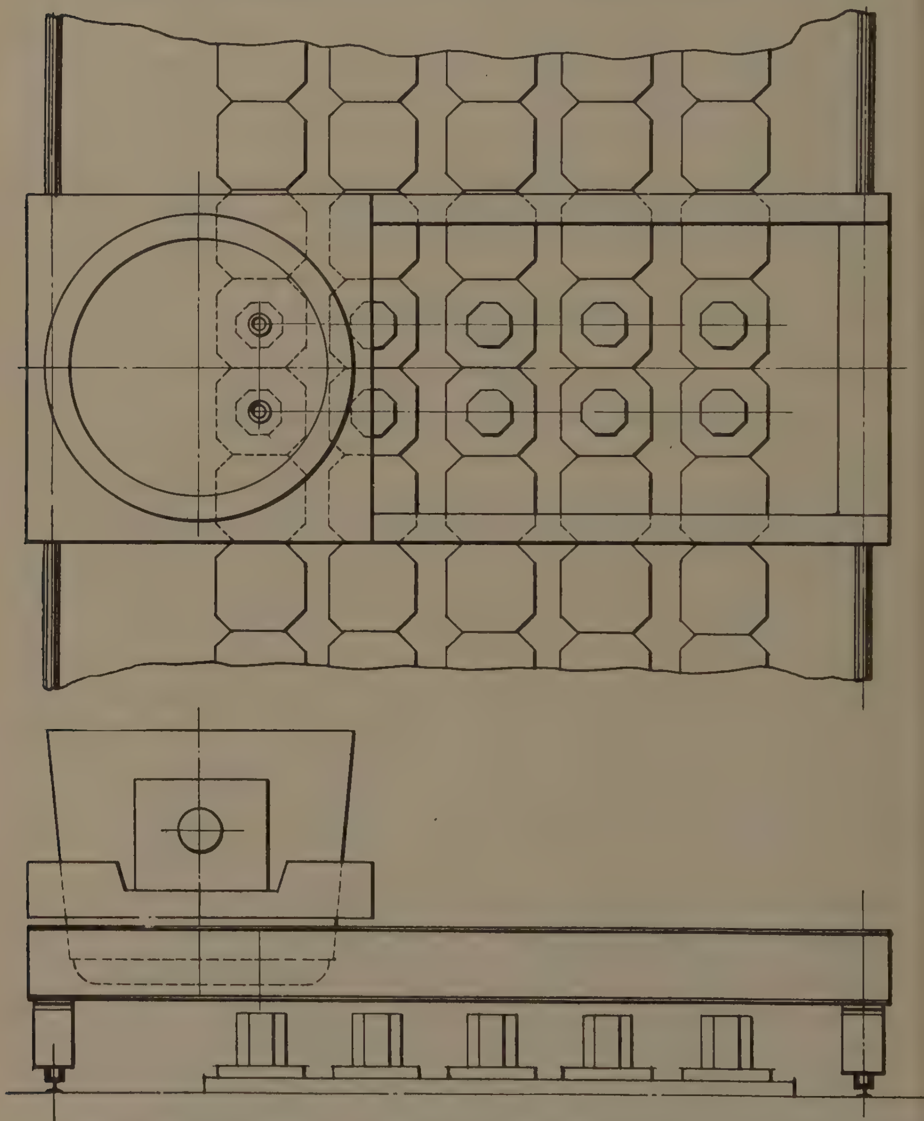


Figure 12—Arrangement of Open-hearth Pit Floor for casting Individual Ingots

900 pounds the tolerance allowed is 10 pounds under and 25 pounds over the ordered weight. As an instance

of good practice in this direction the following record of a heat from one of the 75-ton furnaces at Burnham is given. The layout in this pit differs slightly from that shown in Fig. 12 but the principles are the same. In the heat referred to, 172 ingots of 975 pounds ordered weight were poured and of these only two were outside the tolerance allowed. It is obvious that to obtain results such as this, good ladle and stopper conditions are necessary.

Figs. 13 to 16 inclusive are offered to show the flow of metal in the manufacture of tires and wheels from short ingots. Fig. 13 shows two wheels from 18-inch conical ingots. Fig. 14 shows two wheels from 19-inch ingots one with the flange towards the base and the other with the flange towards the top of the ingot. Figs. 15 and 16 show two tires from 18-inch short octagonal ingots. The points of chief importance is that in all cases the flange comes from a side and not from a corner of the ingot.

Conclusion.

The paper shows that in the manufacture of tires and wheels for the railroad service two types of ingots, the multiple and the individual, are well established in American practice. Entirely satisfactory results can be obtained with either type and the choice between the two in any given case will be determined largely by local manufacturing conditions.

In conclusion the writer has to acknowledge his indebtedness to Mr. O. C. Skinner, Works Manager of the Standard Steel Works Company; Mr. F. B. Bell, President of the Edgewater Steel Company; and to Mr. A. S. Henry, Vice-President of the Railway Steel-Spring Company.

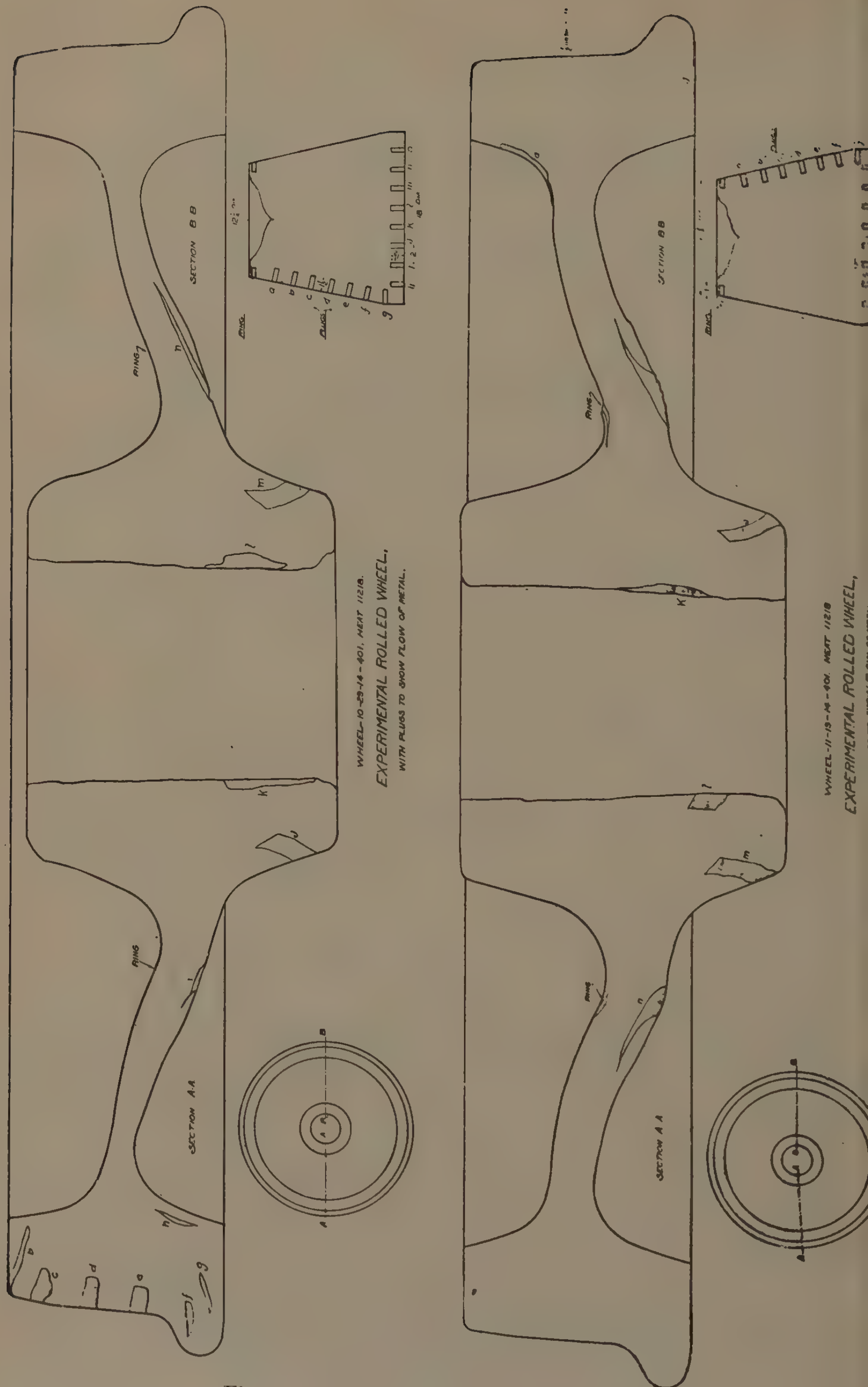


Figure 13—Showing Flow of Metal in Wheels

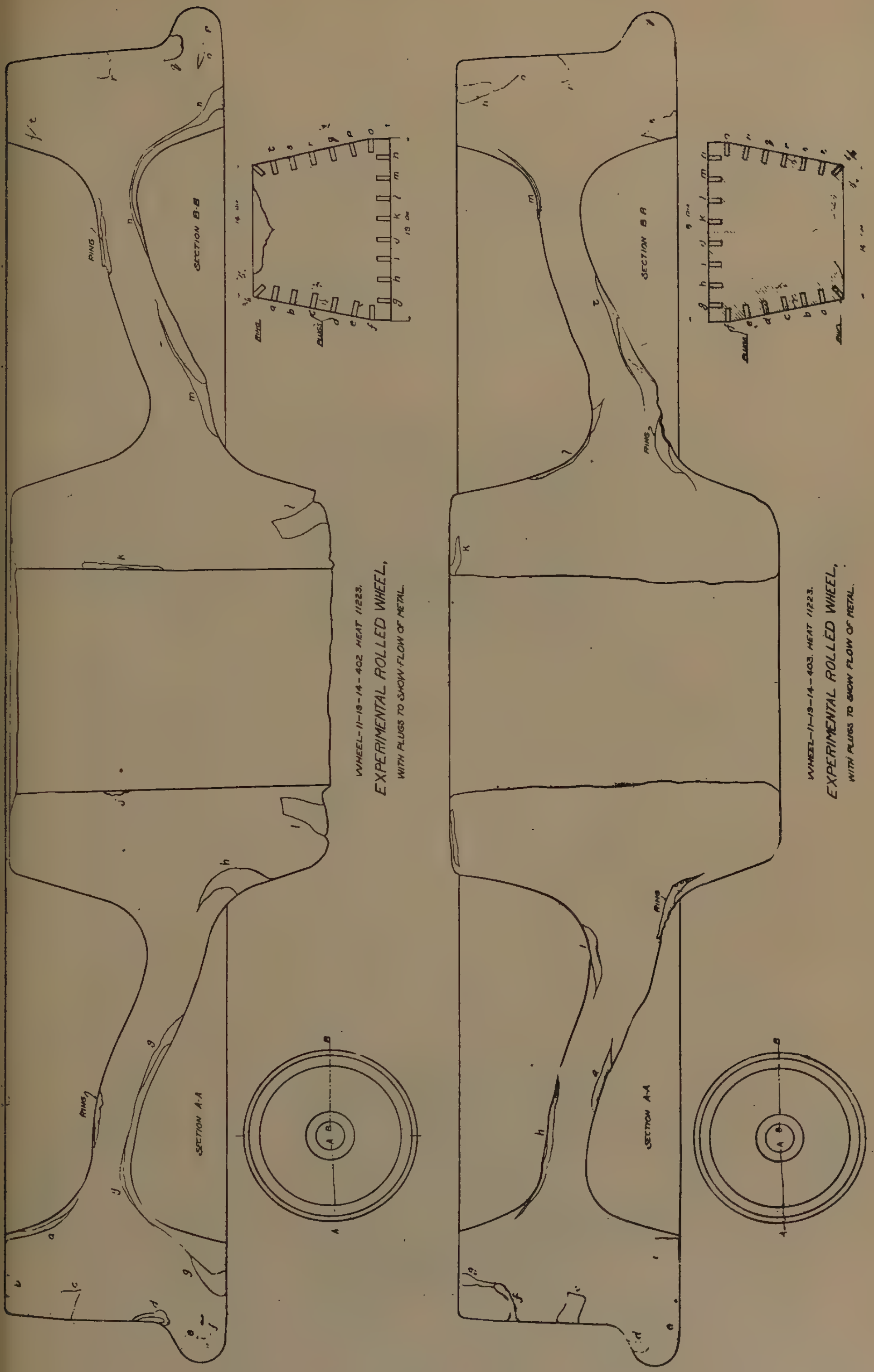


Figure 14—Showing Flow of Metal in Wheels

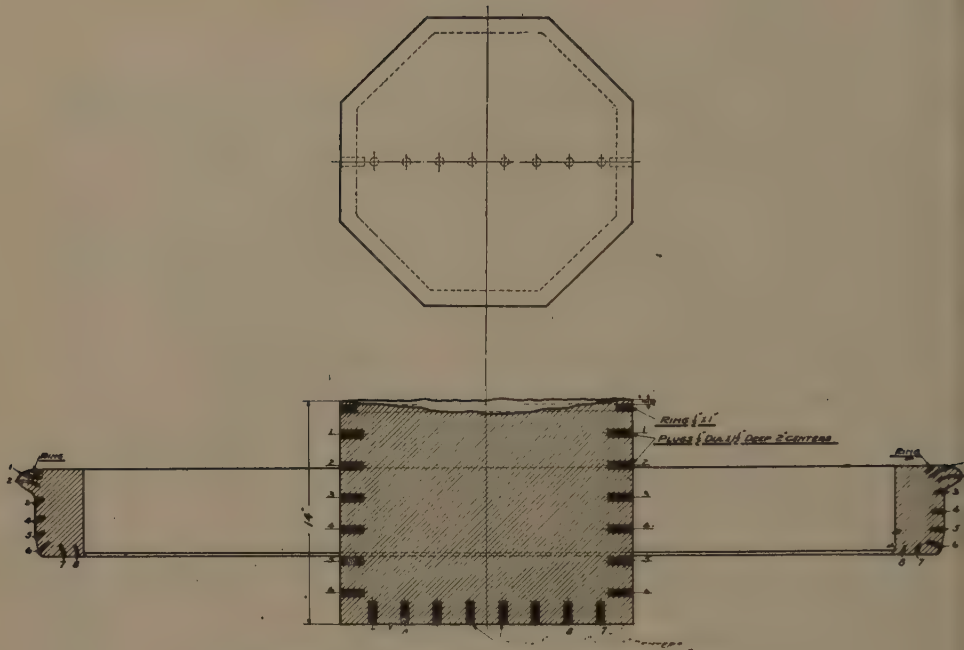


Figure 15—Showing Flow of Metal in Tires

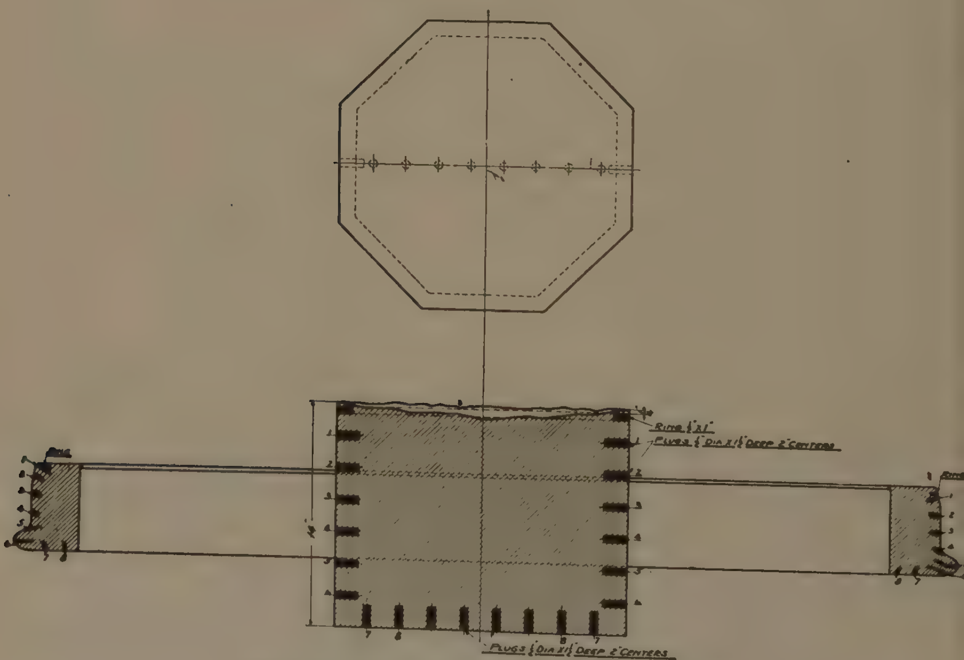


Figure 16—Showing Flow of Metal in Tires

THE MANUFACTURE OF INGOTS FOR LOCOMOTIVE TIRES AND ROLLED WHEELS

Discussion by Guilliaem Aertsen
Assistant to Vice-President, Midvale Steel and Ordnance Company, Philadelphia, Pa.

Mr. Fry's paper is most interesting both as a matter of historical record and as containing novelties in furnace practice.

In discussing it, the writer will omit reference to those points on which there seems to be no difference of opinion, but desires to call attention to a few on which further explanation may be desirable.

Individual ingots were used for tires by the first tire maker in this country in the year 1867 and the practice was almost universal for about thirty years thereafter, the principal exception being that of a tire maker who did not make his own steel, but bought long ingots from steel makers, cut them into blocks at a steam hammer and afterwards proceeded as described by Mr. Fry.

Until about the year 1900 the majority of tires made in this country were made from individual ingots, and these ingots in a variety of molds too great to describe in the limits of this discussion.

Many types were used; top cast, bottom cast, open top, closed top, with and without head boxes, sink heads, etc., etc., in a constant effort to improve quality and avoid the difficulties and dangers that Mr. Fry will agree beset any attempt to cast a large number of small ingots of exact weights from the same open-hearth heat.

The adoption of multiple ingots was postponed, frankly, because of the expense for equipment, and of the extra cost of manufacture. It was the consensus of opinion among tire makers that the cheaper individual ingot was probably "good enough"—little if any trouble was

ever traceable to pipe, either eliminated by the punching or concentrated near the bore of the tire where it was never exposed by wear—but it was never contended that the multiple ingot, from which the piped and defective top was fully cropped and discarded, was not better.

Thus "individual ingots" remained standard practice until about the year 1896, when bottom poured "multiple ingots" began to be adopted and are still used with "hot tops" or refractory head boxes, in which it is common practice to cover the top of the freshly poured metal with material similar to what Mr. Fry describes as "pipe eliminator."

Disregarding relative cost, can there be any difference of opinion as to the relative merits of the two methods?

Mr. Fry's "chemical survey" in Fig. 11 shows a variation in the analyses at different points of the same ingot, which would not be expected nor accepted in blocks cut from a multiple ingot.

In both, the punching (Mr. Fry's 3 per cent. is a large maximum for locomotive driving tires) removes a small problematical part of the center of the ingot where pipe and segregation may be expected. Bear in mind that this punched out piece, about 6 to 10 inches in diameter by 1 or 2 inches thick, is not produced until the ingot or block has been "upset" and its diameter increased about 50 per cent.

With this exception, in the individual ingot all the pipe and top surface defects remain in the resultant bloom and tire. There they are, harmful, or not.

In the multiple ingot the pipe and top surface defects are all eliminated, discarded at the beginning. Nothing more is to be feared on that score.

In the multiple ingot, sliced in a lathe and broken apart, its section, throughout its entire length, can be examined and any accidental pipe or shrinkage detected.

Mr. Fry has referred incidentally to the use of multiple ingots of large cross section, about 4 square feet, rolled to 12″ to 14″ diameter, then sliced into slugs or

blocks, upset and punched as described by him. These have been used for rolled wheels, but not, so far as the writer knows, for tires. It would be of interest to know the effect of this method upon the physical properties of tires, remembering that in a tire the strain is transverse to the longitudinal axis of the ingot and of the bar or billet rolled therefrom.

Such investigation, as Mr. Fry says, is perhaps outside the scope of his present paper.

It is permissible to ask why the circular has been replaced by the octagonal cross section in the individual ingots Mr. Fry describes?

Is the pouring ladle correctly described as a 50-ton ladle? If so, how is the output of a 75-ton furnace divided?

What is the function of the fire brick shown in bottom of 18″ mold in Fig. 7? Is it to protect the cast iron bottom, to prevent splash or to assist the function of the "pipe eliminator"?

What difficulty is experienced due to variations in temperature between the first and last pair of ingots?

Sharing Mr. Fry's emphatic desire for "well made dead melted steel," the writer doubts it as a condition precedent to "pipeless" ingots. Pipe is a symptom of dead melting.

The open-hearth pit organization responsible for the operation which Mr. Fry describes cannot be too highly complimented. Its accomplishment is to be appreciated only by those who have struggled with similar problems. To regularly and successfully get from eighty to one hundred "shut-offs" from each of two nozzles in the same ladle, one keeping step with the other, is a feat.

THE MANUFACTURE OF INGOTS FOR LOCOMOTIVE TIRES AND ROLLED WHEELS

Reply of Lawford H. Fry to Discussion by Guilliaem Aertsen

Mr. Aertsen's discussion coming from one so familiar with the growth and difficulties of tire manufacture is interesting and valuable.

It was not the author's intention to present a brief for either the individual or the multiple ingot but to show the conditions under which both are being used today. It is true that some of the early types of individual ingots have failed to meet the requirements of American practice and were replaced by the multiple ingot. Such ingots are of historical interest only. The modern individual ingot described in the paper is to be judged on the basis of the service it has given in railroad service in the last ten years in parallel with multiple ingot products. The modern individual ingot has met all the requirements of the most exacting service and consequently a discussion of a supposed superiority of the multiple ingot is of academic interest only. The chemical survey in Fig. 11 shows a certain variation in carbon from bottom to top, but taking the average carbon as 0.66 per cent. there are only four points which show real segregation exceeding 12 per cent. of the normal carbon content. These are the two top points in the center column and the two points each side of the center in the top line. These points form a triangle with a base lying on the top surface of the ingot and extending two inches to each side of the center line. The height of the triangle is only two inches. In the process of compressing the ingot to a bloom the center of the ingot top forming the base of this triangle is not expanded, as Mr. Aertsen suggests, but remains four inches across. As the punch used is 7½ inches in diam-

eter, there is an ample margin of safety for the removal of segregation.

Mr. Aertsen asks the reason for the change from a circular to an octagonal cross section for the individual ingots. With the truncated cone section necessary with a cylindrical cross section, the increase in weight is not directly proportional to the increase in height, as the diameter of the cone decreases as the height increases. The range of permissible ingot heights which can be made in a given mold is limited by the diameter of the mold, and with a conical ingot the maximum weight in an 18-inch mold is less than the minimum weight in a 20-inch mold, so that to cover all required weights it is necessary to have molds 16, 17, 18, 19, 20 inches, etc., in diameter. With the vertical sided octagon molds, the same range of heights gives a greater range in ingot weights, and the whole scale of weights can be covered by molds 16, 18, and 20 inches, etc., in diameter. In addition to thus reducing the stock of ingot molds necessary, the vertical walls of the octagon mold make it easier for the ladleman to see the mark set on the interior of the mold, to which the steel is to be poured.

The firebrick in the center of the bottom-plate prevents cutting of the cast iron, and, as Mr. Aertsen suggests, assists the pipe eliminator and mold in controlling the piping.

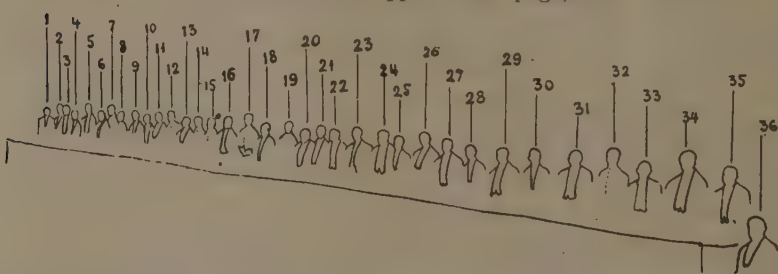
In reply to Mr. Aertsen's comment on dead melted steel and pipeless ingots, and the statement that "pipe is a symptom of dead melting," the author suggests that a more correct form of this truth would be: "Reduction of volume on cooling is a symptom of dead melting. Where the position of the top of the ingot is fixed by freezing immediately after pouring, such reduction of volume takes the form of a pipe and in such cases pipe is a symptom of dead melting." In the individual ingots the pipe eliminator keeps the top in a fluid condition so that it follows as a whole the greater part of the shrinkage of the ingot body. In this way the actual pipe cavity is reduced to a very small space if not eliminated entirely.

VICE-PRESIDENT KING: This brings the afternoon session to a close. I feel that the papers we have heard today continue the high standard of papers read before this Institute and that we are very much indebted to the gentlemen who have come here and read these papers.

It may not be known to some of you that the steel industry is much indebted to Mr. Burgess and the staff of the Bureau of Standards at Washington for their co-operation in the development of scientific appliances of great value to the steel industry. Several of these gentlemen have come here, as you know, and read papers today, but they have also co-operated in the discovery of some very valuable appliances for the steel industry. It seems to me it would be proper and fitting that this Institute give some sort of appreciation of their efforts, and if you agree with me I will ask you by a rising vote to extend the thanks of the Institute to those gentlemen. (The assembled gentlemen arose amidst applause.) The meeting will now stand adjourned. We hope to see you at the dinner this evening.

KEY SKETCH TO CLOSE-UP VIEW OF SPEAKER'S TABLE

(See illustration opposite this page)



1. Horace S. Wilkinson.
2. Harry G. Dalton.
3. Thomas K. Glenn.
4. Joseph G. Butler, Jr.
5. James A. Burden
6. Alva C. Dinkey.
7. Admiral A. T. Long.
8. Admiral F. F. Fletcher.
9. James A. Campbell.
10. Samuel Mather.
11. Willis L. King.
12. Comte Guy d'Oultremont.
13. Eugene Schneider.
14. Colonel Thielkens.
15. General Baron Jacques.
16. Baron E. de Cartier.
17. Albert, King of the Belgians.
18. Elbert H. Gary.
19. Prince Leopold.
20. Henry Clay Frick.
21. George W. Perkins.
22. Prince Reginald de Croy.
23. Lewis Nixon.
24. James A. Farrell.
25. Max Leo Girard.
26. E. A. S. Clarke.
27. Eugene G. Grace.
28. G. Cornell Tarler.
29. Leopold E. Block.
30. William H. Donner.
31. William A. Rogers.
32. Lieut. Baron Goffinet.
33. Henry M. Howe.
34. Robert Hobson.
35. M. Gaston Liebert.
36. James T. McCleary.

EVENING SESSION

The evening session of the Institute was held in the grand ballroom of the Commodore. After dinner, President Gary called the meeting to order and said:

Gentlemen: Five years ago last August the strongest military nation, which for more than forty years had been preparing for war and conquest, determined to attack its neighbor nation. The most direct route in order to make that attack was through the land of Belgium. The German army said to the Belgians, "We have power and destruction in one hand and we have wealth and a promise of benefit in the other hand. We desire to cross your country in order to make a military attack which we have determined upon."

There arose in the land of Belgium a man who said, "I am the King and I am the servant of the Belgians, and we love honor better than riches." (Applause.) "If you will disregard the pledges concerning my country which you have made and will treat them as of no consequence, you have now met people who entertain different notions and who are possessed with higher principles."

The French people waited with bated breath as they saw the German army, well prepared with soldiers and munitions and big guns, approaching by the nearest route to France—waited and sighed and feared and wondered what might be the consequences; and the world looked on. But that splendid type of humanity in the person of the King of Belgium, (applause) in general command of the military forces of his country, thrust his soldiers into the gap, bared his own breast to the enemy and staked the whole life of the nation upon the question of maintaining what he believed to be right and justice. The consequence you know.

The people of Belgium, who were requested to hold for

one week the armies of Germany at Liege and Namur in the line of approach by the German army, held it for several days longer, prevented the German army from immediately crossing the border, and saved Paris, saved France and saved the world. (Applause.)

And, ladies and gentlemen, that highest type of Ruler, that every inch a man, that soldier King has honored us this evening by his presence. (Applause.)

Some of you remember in 1911, when the International Steel Meeting was held in Brussels, that King Albert graciously received us at the Palace, and then expressed an interest in our welfare and in the international convention which had been assembled, expressed a wish for continual friendship between the two nations of Belgium and the United States, and especially stated he was interested in the line of business which we were connected with, because it was one of the basic industries of the world.

Therefore we may with pride recognize the fact that the flags of these two countries are to wave together, entwined in a common cause with others of our friends, and that we may depend upon the steel industry in Belgium co-operating with ours.

As representatives of the iron and steel industry of the United States and Canada we acclaim the King of the Belgians as one of the greatest of them all, and as a sincere friend of our country.

I ask you to raise high your glasses to the King of the Belgians and all his people. (Cheers and applause.)

His Majesty, the King of the Belgians: Gentlemen, I give you the toast of the President of the United States. Allow me to form the sincerest wishes for the prompt recovery of his precious health. (Applause.)

Gentlemen, I thank heartily Mr. Judge Gary for his very kind words, I should say his too laudatory words, he has just addressed me. I thank you all for the especially warm manner in which you have received this toast.

With the permission of Judge Gary I will call him an

old friend of Belgium. It is indeed for me a great pleasure and a real privilege to address an assembly of distinguished representatives of one of the leading industries of this country. Circumstances did not permit me to inspect more than two of your big steel plants; yet I know that the works managed by the men who are here can safely be considered as unrivaled over the world as far as up-to-dateness and efficiency are concerned. There is very much to be learned from you for my countrymen, who are just beginning that long and difficult task of reconstructing their factories ruined by the enemy. The industries in the different countries are in competition, but this peaceful competition leads firmly to scientific progress and the general welfare of mankind. (Applause.)

Judge Gary: Ladies and gentlemen, in every military country there is supposed to be a great steel plant, intended for the manufacture of guns and other war material. Unfortunately in this day and age nations must rely upon strength of that kind in cases of emergency.

I have already alluded to the fact that it was the intention of Germany to secure control and dominance of the entire nation of France. Fortunately there was in that great country an establishment equipped to manufacture the first essentials of military defense. The name of those works is the Creusot Works; (applause) and at the head of those works is a gentleman who has been the president of the British Iron and Steel Institute, and is an honorary member of the American Iron and Steel Institute; and he is present with us on this occasion. I have great pleasure in now presenting him to you. Mr. Eugene Schneider. (Applause.)

Mr. Eugene Schneider: Mr. Chairman, ladies and gentlemen: I want to thank the Chairman for the kind words he has just said about me. And above all I wish to thank the Directors and the Institute for the honor they have bestowed upon me in electing me to honorary membership. As Honorary President of the "Comité des Forges" in France and President of "The Iron and Steel

Institute" in Great Britain, and now, through your courtesy one of yourselves, it is gratifying for me—though my modesty grows alarmed at the thought—to think that, in my triple capacity, my participation in your banquet tonight is a symbol of the alliance between America, England and France, which is the best guaranty of peace in the world.

I have never yet, since my arrival in the United States, been able to realize that I was in a country not my own. The hospitality I have met and the cordiality of the welcome given to me have removed the distance of the ocean. I get the impression that I am with my nearest neighbors, with very old and very tried friends, and I can hardly imagine how it was possible for me to wait so long before coming to shake you by the hand.

This evening, in seeing my excellent friend, Judge Gary, seated near me, a still closer and more delicate sentiment pervades me. I seem to be entering the still more intimate circle of my own family.

An ironmaster myself, I find myself among other ironmasters. The ties of the same profession draw men closer to one another. But, in particular does the art of dominating fire, and forcing nature to give up to man that noble metal upon which most all human construction is based, create among those who practice the art an even closer tie, a most binding kind of solidarity. I feel as though we were joined by the rites of the same religion.

My personal relations with the United States go very far back. My father took part in the creation of the armor-plate industry in certain American plants. Since that time we have maintained most cordial relations. During the war, aside from obtaining steel from you, my workers were in collaboration with yours. We pooled our experience, our work, our devotion to that cause for which we fought side by side, and in this co-operation we have forged a very rare metal, a metal that is invisible and indestructible, the metal of Franco-American friendship.

As we have interests in common and this is the first

time we meet, I guess you expect me to say something about business in France, and in particular about the French steel industry.

Before the war the French iron and steel industry occupied a modest place in the world. France stood fourth among the countries producing pig iron and steel. But you must not forget that she had to work under unfavorable conditions. She possessed large ore beds, but they were situated away from her ports and her rivers, on the very boundary line of her most dangerous enemy. She was also short of good coking coal, and, of coal for general purposes, had a yearly deficit of 23 million tons. French industry had to buy its coal on the outside, one of the chief disadvantages under which it labored.

Nevertheless, between 1903 and 1913, the production of pig iron was increased 87% and steel 150%. I consider this a worthy achievement. In fact, I am under the impression that it has not been accomplished by any other country than the United States. The French steel industry not only succeeded in meeting the needs of its own country, but even began the exportation of appreciable quantities. The war surprised it in full development.

I do not know whether in America you fully realize what the war meant to our steel industry, what a terrible blow the war struck it, and to what an almost superhuman test the industry was put.

Just remember that at the declaration of war most of our directors, engineers, foremen and workmen were mobilized. Sixty-seven per cent. were called to arms. In August, 1914, the majority of our plants, even those situated farthest from the zone of war operations were obliged to close down. The unhappy outcome of the early battles served only to aggravate the situation. The largest steel plants in the east of France and our most productive coal fields either fell into the hands of the enemy or were in the theatre of military operations. As early as October, 1914, France was deprived of the twenty million tons of coal that the mines of Nord and Pas de Calais supplied.

With one blow the steel industry lost 85 blast furnaces out of 156, 48 open-hearth furnaces out of 164 and 53 converters out of 100. Our means of production were reduced 81% for pig iron and 63% for steel, as compared with 1913.

And it had to be just at this time, at the Battle of the Marne, that our Government called upon us for a daily supply of 100,000 shells for 75 mm. guns. We were not producing even 20,000.

Gentlemen, I should not like anyone to pass through the hours through which we lived, the patriotic anguish that was strangling us, the fever that consumed us for long months. We got to work. We convinced public opinion that the Army would have to return part of our staff. We appealed to the devotion of our women. For every woman employed in our metal industries before the war, we employed 390 in 1918. We raised to a maximum the output of the plants that we still retained. We built new ones. We toiled for four years, day and night.

In July, 1915, we had only 20 stacks at work. In January, 1916, we had 40 and in January, 1918, 57. Before the armistice, in September, 1918, we had 59 in operation, 30 were down and 13 in course of construction; a total of 102. Little by little we had made up for the enormous losses caused by the German invasion.

In July, 1915, we had at our disposal 100 open-hearth furnaces, 6 down and 35 in course of construction. In September, 1918, we had 165 open-hearth furnaces in operation, 16 down and 44 in course of construction.

In January, 1916, we had 1305 crucible furnaces. In September, 1918, we had 2459. In January, 1916, we had 21 electric furnaces; in September, 1918, we had 40.

The result of this effort was that for every 100 rifles manufactured in 1914, there were 29,000 in 1918. For every 100 machine guns in 1914, we manufactured 7,000 in 1918.

At the beginning of the war we turned out each day 13,000 shells for the 75s and 200 for the 155s. In 1918

our production was 200,000 for the 75s and 45,000 for the 155s per day.

In 1915, we manufactured only 2,600 75 mm. guns. Two years later we manufactured 10,000.

Our heavy artillery at the beginning of the war can hardly be said to have existed. Everyone knows that the surprise of the first battles of the war came chiefly from Germany's overwhelming superiority in heavy artillery. At the time of the armistice, we had 6,500 heavy guns, 3,400 short 155s, 1,100 long 155s, together with other sizes up to 21 inches. France was thus enabled not only to meet her own needs, but was in a position to equip the entire Serbian army, to send considerable quantities of heavy artillery, rifles and machine guns to Russia, Roumania and Greece as well as to supply the American army with all the field artillery it needed and half the heavy artillery.

I could continue to quote figures that would be equally illuminating in the matter of aeroplanes and tanks. I have thought it interesting to go into the details I have given in order to bring out an important point—that all industrial effort in France during the war was concentrated upon war manufactures. So that, if today we are short of ships to send to the United States for coal, wheat, copper and oil, which we need so much, you must not forget that it is because, for that long period of four years, every bit of our steel was converted into engines of war only.

We now find ourselves confronted at the end of the war with a task no less formidable than the one we have just completed. We have had to reconvert our manufacturing plants to peace conditions just as we had at first to convert them for war needs.

I am aware that there has been a certain measure of talk about a wave of laziness that spreads over Europe. As far as I am concerned, gentlemen, to tell the truth, I should have liked nothing better than to stop working awhile. I assure you, however, that work did not stop in

my factories for a single instant. We wanted above all to cope with circumstances and be ready for the future that the Treaty of Peace opens up to us.

Immediately after the signing of the armistice, the entire staff of engineers and workmen at the plants situated in the districts that had just been freed from the enemy by the allied armies set to work. In all places where systematic destruction had not been completed or where the enemy had had no time to finish his dastardly work before his hasty retreat, the equipment that was left was put into working order. Today, the iron mines, blast furnaces, steel plants and workshops are again in action.

As you know, the restitution of Alsace-Lorraine is also of very great importance to the French steel industry.

The resources of the iron ore beds are estimated at 1,832 billion tons, and the annual production of the Lorraine district which was formerly under German domination equalled 21,156,000 tons. This will double the ore production in France and will make her by far the largest ore producer in Europe.

Alsace-Lorraine possesses 66 blast furnaces, producing 3,870,000 tons of iron, and 26 converters and 10 open-hearth steel furnaces that produce 2,286,000 tons. This additional production of pig iron and steel not only covers the present needs of France but leaves a surplus for export.

Including the production of Alsace-Lorraine, France now stands second as an iron and steel producing country, excelled only by the United States.

The situation may be summarized as follows:

Iron ore 22,000,000 tons before the war.
Iron ore 43,000,000 tons after the war.
Pig iron over 5,000,000 tons before the war.
Pig iron over 10,000,000 tons after the war.
Steel over 5,000,000 tons before the war.
Steel over 8,000,000 tons after the war.

We shall only derive the fullest advantage, however,

... the equipment that was left ... in working order. Today, the iron mines, ... furnaces, steel plants and workshops are again in ...

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Pig iron over 5,000,000 tons before the war.
Pig iron over 10,000,000 tons after the war.
Steel over 5,000,000 tons before the war.
Steel over 8,000,000 tons ... war.

We shall only derive th... e, how...

We shall only derive the fullest advantage, however,

through increased production and close co-operation between employers and workmen.

We have, of course, experienced social unrest like other countries, on the morrow of the war. We were among the first to experience it, and at a time when we were particularly sensitive to it, which is probably the very reason why we have gotten further ahead in this matter than other nations.

We reached the crisis between last May and July, but common sense and moderation prevailed. The Union of Steel Workers and the General Labor Federation which assembled at Lyons in September both repudiated the agitators who sought to lead them along the road to Bolshevism. The international strike that was called for July 21st was a complete failure. It failed in France because the workers refused to follow the extremists.

Gentlemen, I should not like to say anything here that might appear to be an allusion to happenings in this country. I should be lacking in the discretion that American hospitality imposes upon me. What is more, the elements of the social problem in your country and in mine are vastly different. Legislation is different. The wage-scale, the mental attitude, life itself is different.

As far as I personally am concerned, I find the solution of the social problem in good sense, good will and co-operation. In my country, a certain number of individuals are making a special effort to convince the workers that men are divided into two classes:

The privileged class represented by employers and the oppressed class that is represented by the workers.

For my part, I must confess that I do not know what is meant by a class composed of employers or a class of workers. I can distinguish no classes. I discern only men hard at work. Nor, alas! do I find that I have more leisure or fewer cares than my workers.

I consider the workers in my plants as my collaborators and friends, just as my father and my grandfather did before me. The task at which we are working together

involves certain duties that I have towards them, which I carry out scrupulously, and I try to improve the conditions of life and work of my employees.

On the other hand, my employees have certain obligations towards me which I expect them to carry out.

For the past twenty years, the workers in my plants have elected their own representatives. I no more ask them whether they are union men than what is their religion. At regular intervals we discuss with those representatives all questions relating to the condition and the work of my employees. We listen to all the suggestions, advice and criticism they offer. But it is equally understood that I reserve for myself the right to make decisions and to issue orders and not because I believe it a privilege that belongs to me individually. As an individual I have nothing, so to speak, to do with the case. The task that we have in common is the only thing that counts, and I enter into consideration individually only in so far as no human enterprise can succeed without a guide or a leader to direct it. The same principle holds equally good for times of war or peace. I feel my duties of leadership. I feel also that I shall never allow violence from without to impose measures that I deem against the general welfare.

The victory of the allies has inaugurated a new era among peoples of the world. We may even hope that mutual understanding, based on friendship and common sense, will gradually take the place of violence, and will prevail also in the relations between citizens of the same country. Without this understanding, there can be no real progress.

Judge Gary: Mr. Schneider has been talking to the whole world, and all are listening. And the sensible people will listen to, and apply what he says. The last time I had the pleasure of seeing Mr. Schneider he and I crossed the English Channel together and we little thought then that what has happened since would ever occur. For at that time we and all other steel makers

were exceedingly friendly towards, and co-operating with the Germans. It only shows what time will bring forth.

I am now going to present to you a gentleman with whom and with whose work you are well acquainted. Like myself, born on a farm, and proud of it, educated at Annapolis, experienced in building ships and engines, and at last reduced to the low grade of politics. Mr. Nixon, as sole member of the Public Service Commission in New York, succeeding by the last enactment of the Legislature on the subject six or seven Public Service Commissioners, is actually advocating an increase in the fares on the street conveyances of this city, which you and I have to pay. But his sole reason and argument are that he believes it is necessary in order to permit the railroad companies to live, that the accounts show to a demonstration that unless the fares are raised the expenses which are incident to the conduct of the business cannot be paid. If that is any excuse, then he has it.

Now, gentlemen, it is my very great privilege to introduce to you Mr. Lewis Nixon.

Mr. Lewis Nixon: Judge Gary, ladies and gentlemen: It seems unbecoming that a mere Commissioner of Public Service should talk to men who have been bringing their minds to the wonderful developments of the steel industry; but even in that we have some connection, as I shall tell you.

Judge Gary has been fighting a great fight, and stands out as the great leader of thought in the United States against a species of industrial Bolshevism. (Applause.)

It may be that in a minor field I have had to combat something of the same kind, in a political way.

Now, it is all very well to charge me with wanting to raise fares, they say to eight cents, yet at the same time, through lack of co-operation, the people are paying up to fifteen or twenty cents. Now, I could go on and talk back to the Mayor of this great city, who is undoubtedly well intentioned, but badly advised (laughter), and say that I possibly were doing better than he is. Just as the

man who said so proudly to his neighbor that he was more temperate than he was because he put more water in his whiskey. (Laughter.) But the situation in this connection, gentlemen, is too serious. Those of you who live in New York must understand it.

Upon taking office I had the strange idea that the matter of regulating service meant, among other things, that I should so act as to prevent the destruction of a service which I was supposed to regulate. (Applause.)

Had the City of New York been alone and found that its fares needed raising in order to prevent destruction of property, plant and equipment and demoralization of organization, I should have thought probably that it was due to extravagance, incompetence in management or other causes that should be sought after. But when 75 per cent. of all the cities of the United States of over 25,000 inhabitants have met the same conditions, it was time to take notice and clear our own house. It is a problem which has to be met. Bankruptcies must cease. And yet the great City of New York, the leader of the world's metropolises, faces the situation today of bankruptcy of every one of its transportation companies by the 1st of January unless needed relief is given. It is probable that relief cannot be achieved unless the people themselves rise and demand that orderly and due processes of taking care of the invested capital shall once more prevail in this great city. If they do not, this city, which has to rely upon credit, will find that it is faced with repudiation and forced bankruptcies.

Transportation in New York compares more than favorably with that of any other city on the face of the earth. It is equal in mileage to London, Paris and Chicago combined. Wherever we see a capable and able man throughout the country, he is brought here. We are carrying great crowds, far beyond the capacity even that we expected at the time the subways and elevated roads were built, a capacity now overtaxed over 50 per cent., with absolute safety, and in a way that men can depend

upon reaching their offices or their places of business without danger from accident and with surety that they can almost set their watches by the running of the trains. The management of the subways in the rush hours is almost equal to that of a moving platform. And yet this great system is today hanging in the balance and is liable to deteriorate to a degree that I cannot tell you.

Most of you know what it means to have a receivership of anything, and the whole New York transportation system is practically in receivership; the last parts will go in by the 1st of January.

This is a sad situation for the men of this city to face. It does no good to say that it can be remedied by drifting, that this will remedy itself. It cannot be done except by a matter of fact and common sense and businesslike recognition of real conditions, and the stopping of an endeavor to go against what economic law proves the best and proper way. It is an unpopular job to be a Public Service Commissioner.

Every man, woman and child who pays a two cent transfer charge realizes of course that they are paying the two cents. They do not know that they were saved from paying five. But they are beginning to realize it now, and, as I say, the public voice will soon be uplifted, and I look for a betterment, and believe me within a few years, if we can get the proper readjustment of the cost of service which every self-respecting American is willing to pay, and pay too for what he gets in the degree that it is worth, that we can bring back not only a universal fare in the City of New York with free transfers, but a fare even less than five cents.

Now, how does that affect you gentlemen? I am today subject to pin-pricking and abuse. I am said to be above the law, and that I have done a lot of things that are not warranted by the law. I want to say that the only way I am above the law is that in whatever I have done I feel that I was fully supported by the law which I have acted under, and I have taken such responsibility in the

interests of our people, the people of the City of New York, and I shall continue to take such responsibility as long as I stay in office. (Applause.)

There is another phase of this situation which you gentlemen should consider. As soon as the present cloud has passed and we have something really to regulate in the interests of the people, we shall find that the subway and elevated systems and the rapid transit systems of the City of New York are so vastly overtaxed that we shall at once begin to plan and project greater and further extensions. You will note back in history, with the smaller towns, when we had no way of getting about, a man wanted to get from where he lived to where he worked in about an hour; that was from three to four miles when men walked, from seven to eight miles when men drove. And now we expect to bring them twenty miles. I expect you master men in the steel industry not only to realize that there is a tremendous opportunity in this field for the very work that you are turning out, in our future subways, but I want your genius to so apply that men can get, in the next twenty years—and a man will have to, as this great city increases—into the city from probably forty or fifty miles within an hour with the same safety and same certainty that he does at the present time. So there is something to look forward to in the steel industries as far as the upbuilding of New York is concerned, because New York is being rebuilt in steel throughout all its surface, throughout its underground; and we have only begun to build, because the demands upon us are increasing with such rapidity that it is a case of not being able to keep up. So I can only say that it is a cheering word that I am able to speak. I do not believe that the opposition which has heretofore held against manifestly proper and honest means can long prevail and win out; when they have passed away and the people come into their own, we will have the proud privilege of continuing our pride in the wonderful transportation systems of this city. (Applause.)

CLOSE UP VIEW OF SPEAKERS TABLE, SEMI ANNUAL DINNER OF AMERICAN IRON AND STEEL INSTITUTE AT HOTEL COMMODORE, NEW YORK, [illegible]

JUDGE GARY: I hope no man will leave the room unless he is obliged to. Something good is coming.

In the French Consulate of this City for several years last past there has been in charge a Frenchman who has honored the position, who has benefited his country by splendid service and who has increased and cemented the friendship between France and the United States to a material extent. We are proud of his acquaintance, we are glad of his friendship and we are delighted that he could be with us this evening.

I have the honor to introduce to you M. Gaston Liebert, Consul General from France.

M. GASTON LIEBERT: Judge Gary, ladies and gentlemen: I should feel conceited tonight having to speak after a king, and such a king as King Albert, and after such prominent men as Mr. Schneider, my worthy compatriot, and Mr. Nixon.

They have spoken to you in words that you best understand. They have spoken to you technically. I am quite certain that what Mr. Schneider in particular told you reached your minds and also your hearts, because I know what the Americans have done for us not only since you came actually into the war, but long before that, at the time you were supposed to be neutral. (Laughter.)

I came to this country at a time which was almost tragic, when France needed not only the courage of her children at the front, but also the intensified work of her men in the factories, and even that work was not sufficient and would not have been sufficient to carry us to victory had it not been for the co-operation, the hearty co-operation of the men of the iron and steel industry of America.

Mission after mission came from France to these shores to come in contact with your factories, to tell you of our needs and to get from you everything that we needed for a new balance of military power, and we got it—notwithstanding certain opposition which came, you know where from. Well, that co-operation went on closer and

closer, more and more efficiently, after the French High Commission was organized a little over two years ago.

It seems that now we have turned the page, that war being over—technically over at least, on the western front, because it seems that there are many wars being waged on the eastern front—that our co-operation is at an end. Well, I say that it is only beginning, and I am quite certain that during this period of reconstruction of France, reconstruction of our industries, which as Mr. Schneider explained have now to be transformed again to a peace working basis, that you will co-operate most heartily with us in supplying French industry when needed with certain raw materials that she might not have in sufficient quantity, and also machinery which we need in great quantity, and in as short a time as possible, for France must begin to export again some manufactured goods to put her financial system on a sound basis.

You know how thrifty the French people are and how hard working they always have been; so anything which is done in that direction of co-operation, industrial and financial, will be done as a good investment. The guaranties are excellent; you know it. The credit of the French Government and the French nation has always been of the very first grade, so whenever long credits are needed by our industry you may be certain that it will be a good investment for the people of this country. I need not insist upon this point, especially as I am not a technical man and I am talking of these questions only generally.

There is one point to which I think, although I am not a technical man, I might draw your attention. Allusions have been made tonight to the danger of Bolshevists and I am rather free to speak about it, as my great and honored chief, M. Pinchon the French Minister for Foreign Affairs, only a week ago declared publicly in the Chamber of Deputies that France was at war against Bolshevists; he said it publicly, so I think I might be

allowed to say that I consider Bolshevism wherever it is, as a real, great danger, which all of us must look in the face.

I am very much honored to be here tonight. I was very pleased to come here tonight to have the opportunity to express my admiration and my deep respect for a man who is here tonight, who is your president and who certainly in the course of these few weeks has done more not only to fight Bolshevists in this country, but all over the world; he has set a good example of courage, of determination and energy, which we should all honor and strive to imitate whenever the occasion arises. (Applause.)

Judge Gary has shown that he has one of the greatest qualities that a man can possess, and that is civic courage. In the fight which he has had the energy to start, he has shown a sense of justice, a clearsightedness which I think will carry its point. He has made the distinction between people of good faith and those of bad faith. He showed that he was ready to talk to the proper ones and he would not talk with the others, who are the Bolshevists.

I am pleased to say that publicly to him, as a friend, and as an admirer of what he has done. We all know him but we like him more now that we know what he is capable of doing.

Let me thank you again, gentlemen, for your very kind and charming hospitality. This meeting is really most representative, and representative of one industry of great strength in this country. I am quite certain that this strength will be put as much as possible at the disposal of your friends on the other side of the water, and that Franco-American co-operation in industry will be as close during peace as it has been during the war, and that it will bring us also to a mutual victory, the victory of peaceful aims in the interest of humanity and civilization. I thank you. (Applause.)

Judge Gary: I am very grateful to M. Liebert for his

kind expressions, but I repeat what I said to a number of you at the meeting this morning, that although I happen to be in a position where my name was used as taking a leading part in the movement which has been referred to, yet my strength came from the fact that I had behind me and with me in strong support a finance committee of seven men, a board of directors of fifteen men, a splendid organization made up of officers of the steel corporation and its subsidiary companies, of the larger portion of the workmen, of every member of the American Iron and Steel Institute, of the throngs of people all over this country who by telegrams and letters sent from Chambers of Commerce and other large associations and partnerships and groups of individuals and single persons,—men and women, stockholders, wage earners, members of every different walk in life, located all over the United States—expressing words of sympathy and commendation; and besides an intelligent, honest, fair minded public press, all in strong support of a principle which at this juncture had to be fought out to the end until it was made certain that right and justice should prevail. (Applause.)

By your indulgence I should like to say one or two words in regard to the statement that Bolshevism is to be feared, even in this country. I admit it is to be feared, in the sense that the bandit, the burglar, the robber or any other criminal is to be feared, lest he do harm; but in this country, where the citizens in the main are loyal and patriotic, and stubborn in the defense of principle, there is no danger from Bolshevism, which would threaten the nation or threaten civilization.

Now, ladies and gentlemen, I have saved for your delight and entertainment a gentleman who is a member of the profession upon which all nations rely for defense of their country and for offense, when necessary, upon the high seas which surround us, in charge of a branch of the military which is the first to be attacked and the first to commence an attack, and which is relied upon to furnish the transportation of the land fighting power, the

troops necessary to be transported from one place to another, the arm of the Government which protects our land, which protects our commerce, which protects our nation.

It is my pleasure now to introduce to you Admiral Fletcher.

Admiral Fletcher: Mr. Chairman and members of the Institute: The last time I had the pleasure of meeting many of the members here tonight they were deeply absorbed in the problem of how to get from their factories the maximum output in the minimum time.

I do not think that we all realized at that time how the industries of this country were to prove the dominating factor in the part that we played in this war.

But those problems are now past, and we hope that the industrial life of the country will not be again diverted from its useful channels.

This war is too near us to view its lessons in true perspective, but there is one thing that was forcibly brought home to us, and that is the vital importance of the great industries in this country in the conduct of war; and this applies to both the personnel and the material.

We have in Washington a very efficient Government for conducting the affairs of peace, but when we were confronted with a great emergency it was found that the machinery of the Government was too small and entirely inadequate to conduct a great war, more particularly a war in which we not only had to mobilize the military forces, but all the industrial forces. When the Government was confronted with this condition there was summoned to Washington some of the ablest men from every industrial walk, and from nearly every part of the country. These men came forward and unselfishly and patriotically devoted their talents and their time to the service of the country. They started in without any organization, without any precedents to guide them, and with very little authority of law; but they took charge

and regulated or practically controlled almost the entire industrial output of the country.

Furthermore, the industries of the country, by their co-operation, met these men more than halfway. I regard the work of these men who formed the various war boards in Washington and the leaders of industry who joined hands with them, to mobilize our factories for the output of material, as one of the greatest achievements of the war. The knowledge that we gained then of what to do and how to do it will remain one of our great assets in any future war.

I am pleased to take advantage of this opportunity to pay tribute to and give credit to the energies and resourcefulness of the directors of our industries, and to the men who labored in our factories to produce the enormous amount of equipment required for the army and the navy. (Great applause.)

JUDGE GARY: I should have said Admiral Fletcher was one of the members of the War Industries Board. We steel men know that he was always fair and reasonable.

In looking over this vast audience during the dinner from one end to the other several times, his Majesty, the King of Belgium, finally said, "This is a fine lot of men." I replied to him "Your Majesty, I guarantee your endorsement." (Applause.)

Thanking you all for your presence today and this evening, for the splendid work you have been doing and for the interest you have shown in the cause of industry, justice and progress and right, I bid you good night.

SEMI-ANNUAL DINNER OF THE AMERICAN IRON AND STEEL INSTITUTE IN THE GRAND BALLROOM OF THE HOTEL COMMODORE, NEW YORK, OCTOBER 24, 1919.

PARTICIPANTS—MAY MEETING

(* Guests)

Abbott, Franklin E.
Agnew, John D.
Ahlbrandt, G. F.
Ahles, R. L.
Akin, Thomas R.
Alder, T. P.
Alderdice, George F.
Alexander, C. A.
*Alfred, W. J.
Allen, James P.
Allen, John N.
*Allen, Walter
Allen, William H., Jr.
Alley, James C.
Amaden, E. A.
*Amis, F. W. T.
Anderson, Brooke
Anderson, Mr.
Anderson, Nils
Andrews, J. I.
*Anson, S. M.
*Anthony, C. A.
*Anthony, George A.
*Armsby, George
Armstrong, V. C.
Assmann, F. A.
Atcherson, R. W. H.
Atwater, C. G.

Baackes, F.
Bailey, Edward
*Bailey, Guy L.
Bailey, R. W.
Bailey, William M.
Baily, T. F.
*Baird, C. R.
Baird, Frank B.
Baker, E. D.
Baker, Merrill G.
Baldwin, H. G.
Baldwin, Louis S.
Baldwin, R. L.
Balkwill, George W.
*Balliett, B. J.
Balsinger, W. R.
Baltzell, Will H.
*Bancker, W. F.
Barba, W. P.
*Barber, E. J.
Barbour, H. H.
*Barbour, James W.
*Barclay, J. Searle, Jr.
*Barker, Alfred K.
Barnes, C. A.
Barnes, Edwin F.
*Barnhart, Harry
Barrett, J. C.
Barrows, W. A., Jr.
*Bateman, James B.
Battelle, Gordon
*Bauer, H. E.
*Baylies, Fred N.
*Beal, J. P.
Beale, A. H.
Beale, Harry S.
*Bean, Henry Willard
Beatty, R. J.
*Beaver, C. W.
Beaver, Harry C.
*Becker, F. O.
*Becker, L.
Beegle, F. N.
*Bell, Ernest E.
Bell, J. E.
*Bell, Walter E.
Benner, Samuel A.
Bennett, C. W.
Bennett, D. P.
Bennett, William H.
Bent, Quincy
Bentley, F. T.
Berger, C. L.
*Best, Leigh
Bigelow, F. A.
Biggert, Cassius F.
*Biggert, Harry H.
Bigler, F. S.
Bihler, L. C.
Bindley, John
*Bird, J. P.
*Bird, Samuel, Jr.
Birney, Emmet H.
Blackwell, Harry E.
Blakeley, George H.
Blowers, Wiliam B.
Blum, Julius
Bole, H. B.
*Bonitz, Walter
Bonner, James B.
Booth, C. E.
Booth, Lloyd
Bourne, H. K.
Boutwell, Roland H.
Boutwell, Roswell M.
Bowron, James
Boyd, P. M.
*Boyden, Charles
Boynton, A. J.
Bradley, W. J.
*Brady, N. F.
Braid, A. F.
Brainard, J. W.
Braine, L. F.
Braman, H. S.
Bramer, S. E.
*Brandler, C. F.
Brassert, H. A.
*Brevoort, W. H.
*Briggs, Carl
Brion, A. E.
*Brion, L.
*Brooke, D. Owen
Brooke, George, 3rd
Brooke, Robert E.
*Brookings, Robert S.
Brooks, J. J.
*Brooks, Paul
Brown, Alexander
Brown, Charles M.
*Brown, Eugene L.
*Brown, Frank L.
*Brown, H. B.
*Brown, Lloyd
Bruce, Robert A.
Brueckel, L. D.
Brunke, F. C.
Bryan, C. W.
Buck, C. A.
Budd, R. B.
Buffiington, E. J.
Bull, R. A.
Burden, James A.
*Burdick, Irving E.
*Burke, George A.
Burns, Timothy
Burt, D. A.
Butler, Gilbert
Butler, Joseph G., Jr.
*Butt, Howard

Camp, J. M.
Campbell, J. A.
Campbell, L. J.
*Campbell, R. D.
Campbell, R. W.
*Canda, Abeel
*Carlisle, Louis H.
Carnahan, Roy
Carney, Frank D.

*Caroll, A. W.
*Carpenter, L. G. W.
*Carpenter, N. L.
*Carpenter, W. T. C.
*Carrier, S. C.
*Carroll, E. H.
Carruthers, J. G.
Carse, Henry R.
*Carson, George C.
*Case, Oliver T.
Champion, D. J.
Charls, George H.
Christ, E. W.
Christian, A. W.
*Clarage, E. T.
*Clark, Arthur J.
Clark, Edward F.
Clark, F. E.
Clark, John B.
*Clark, John B., Jr.
Clark, R. W.
*Clayton, F. W.
Cleveland, de Courcey
Close, C. L.
Cluff, Charles C.
Clyde, W. G.
*Cobb, A. P.
Cocy, Stewart C.
Coffin, William C.
Cohen, F. W.
Colladay, Frank H.
*Colling, A. F.
*Collins, Colonel
Collins, C. A.
Collins, E. C.
Collord, George L.
Comstedt, J. F. A.
*Condit, E. A.
*Conneen, A. M., Jr.
Connell, F.
*Connick, H. D. H.
Cook, Harry H.
Cook, Howard H.
*Cooper, A. C.
*Cooper, W. L.
*Copley, I. C.
Corbett, W. T.
Cornelius, Henry R.
*Corry, William
Cort, S. J.
*Coudee, DeForest
*Coursen, W. L.
*Cowan, George R.
Crabtree, Fred
*Craig, W. W.
*Cranwell, Thomas G.
*Craven, J. C.
*Crawford, H. C.
Crewe, L. C.
Crispin, M. Jackson
Crockard, Frank H.
Crocker, George A., Jr.
Cromwell, J. C.
*Crouse, C. L.
Cummings, S. H.

Daft, Andrew C.
Damerel, George
Danforth, A. E.
Darlington, Thomas
*Davaux, Colonel
Davey, W. H.
Davies, George C.
Davis, Arthur L.
Davis, Charles C.
Davis, H. J.
*Davis, Roy H.
Davis, S. A.
*Davis, Samuel
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Davis, W. W.
Davison, J. V.
Dawson, Thomas C.
Dean, Wm. T.
Deericks, Joseph G.
Deetrick, J. W.
*de Golyer, A. G.
De Lano, S. P.
*Delprat, G. D.
*Demerest, J.
Dennis, M. S.
Desmond, John F.
Dette, William
Deutsch, Lee
Deutsch, Samuel
Devens, Richard
Dickey, W. C.
*Dickson, H. C.
Dickson, William B.
Diehl, A. N.
Dilks, Lorenzo C.
Dillon, John
Dinkey, A. C.
Dinkey, Charles E.
*Dixon, M.
*Dixon, William J.
*Doane, George B.
Donner, Joseph W.
Donner, Robert N.
Donner, W. H.
*Donovan, W. F.
Dorman, A. D.
*Dorman, P. O.
Downer, J. W.
*Downey, R.
Dows, David
*Doyle, N. A.
Drake, Fred R.
Draper, T. P.
Dreifus, Charles
*Dripp, Harold
Duane, James, Jr.
DuBois, H. C.
*Duff, S. P.
Duncan, John
*Duncan, T. S.

Early, George P.
*Earp, C. H.
Eaton, C. D.
*Edgerley, W. H.
Edwards, J. H.
Edwards, V. E.
*Egelhoff, George T.
Eldridge, S. E.
Ellis, Charles B.
*Ellis, J. M.
*Ely, Carl B.
*Emerson, Harrington
Enck, W. B.
Endicott, George
Eppelsheimer, D.
*Evans, Frank E
*Exstein, Henry L.
Eynon, David L.
Eynon, D. L.

*Fagan, J. J. P.
*Farmer, Malcolm
Farrell, James A.
*Farrell, J. J.
Fedder, W. P.
Fehling, O. J.
*Fentzke, Walter E.
*Ferguson, Geo. M.
Field, H. E.
*Fillius, George T.
Findley, A. I.
Fisher, Charles A.
*Fisher, H. F.
Fitch, W. H.
Fitzpatrick, F. F.
Floersheim, Bert
*Foley, H. S.
Follansbee, Wm. U.
Follet, Louis
*Fontaine, S. S.
Foote, G. C.
Forbes, W. A.
*Force, C. Warren
*Forrester, William A.
*Forster, B. D.
Forster, C. H.
*Foster, Frank B.
*Foster, H. M.
Foster, J. F.
*Foster, R. L.
Fowler, A. A.
Francis, Lewis W.
Frank, Isaac W.
Fraser, Allan
Fraser, J. S.
Frazer, Fred
*Freeman, Roger M.
*Frew, Walter E.
Freyn, H. J.

*Frost, Frank R.
Fry, John A.
*Fry, R. M.
*Fuhrer, M.

*Gable, H. C.
Galvin, J. E.
Gardner, K. C.
Gardner, William
Garry, A. H.
*Garvey, Hugh J.
Gary, E. H.
Gathmann, Emil
Gayley, James
Gellert, N. H.
*Gerhausen, W. H.
Gerry, Roland
Gessler, Theodore A.
*Gier, J. W.
Gillispie, R. W.
*Gilmore, Thomas, Jr.
Girl, Christian
Glass, John
Glenn, Thomas K.
*Gockeler, Charles
Goddard, John N.
*Golbraith, A. T.
*Goode, H. A.
Gordon, F. H.
Grace, E. G.
Graff, Everett D.
Gray, J. H.
Grayson, Sidney A.
*Greene, Charles L.
Greenawalt, John E.
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Gresham, W. B.
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Griffith, D. M.
Grose, James H.
Grugan, Justice F.
Gruss, William J.
Guba, Philip M.
Gulick, Henry
*Guntert, Edward E.

*Hackett, John C.
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Hadley, W. E.
*Hagerty, George V.
*Haggstrom, Gustaf
Hall, Francis J.
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Hamill, Lawrence
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Hammond, James H.
*Hammond, Robert R.
Hanlon, W. W.
Hansell, N. V.
*Hardenbergh, W. P.
*Hardenbergh, Henry
*Harder, George A.
Hardy, Francis H.
Harrison, E. W.
Harrison, H. T.
Hart, Charles
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*Haslam, E. H.
*Hastings, J. L.
Haswell, John C.
Hatfield, Joshua A.
*Hawley, Wm. P.
*Hayes, J. E.
*Hayes, G. O.
*Hayman, E. J.
*Hays, W. C.
*Hazen, William E.
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*Hedgcock, W. E.
Heedy, Henry W.
*Helm, Franklin
*Hendricks, W. H.
Hendricksen, J. J.
*Heneage, H. K.
Henshaw, John O.
*Hess, W. I.
Heyward, Thomas R.
*Hibbard, Henry A.
*Hibbard, H. D.
Hickok, Charles N.
*Higgins, Dean
Higgins, W. B.
Hilands, J. P.
*Hilderbrant, H. C.
Hildreth, Thomas F.
Hildrup, W. T., Jr.
Hine, S. K.
Hird, R. G.
*Hitchcock, James W.
Hobson, Robert
*Hodge, Edwin, Jr.
Hoerle, Frank D.
Hoffer, Allen
*Hoffer, Allen R.
Hoffman, W. L.
Holbrook, Percy
Holding, J. C. C.
*Holliday, Frederick T.
Holliday, J. S.
Holloway, H. F.
Holmes, C. O.
Holmes, J. H., Jr.
Hook, A. S.
Horner, W. S.
*Hosmer, Harry A.
Hotchkiss, C. W.
House, Allan C.
Hovey, Otis E.
Howard, Clarence H.
Howard, John J.
Howell, Alfred C.
Howland, H. P.
*Howland, S. W.
*Hoyt, Colgate
Hoyt, Elton
Hubbard, C. W.
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Hudson, A. H.
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*Huffman, O. C.
Hufnagel, F. B.
*Hughes, Edward
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*Hughes, E. P.
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Hulick, Wm. H.
Hulst, John
Hume, J. E. N.
Hunt, A. R.
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Hurd, H. M.
Hurlbert, Wm. G.
Huston, A. F.
Huston, F. R.
Hutchinson, O. N.
Hyatt, W. E.

*Igoe, Andrew
*Igoe, James
Irons, Robert H.
Irvin, W. A.
Ives, E. L.

*Jackson, V. P.
James, Henry L.
Jameson, A. H.
*Jayne, D. W.
*Jennings, William
Jewell, T. M.
Johnson, A. L.
*Johnson, D. M.
Johnson, Frank H.
*Johnson, J. Ford, Jr.
Johnson, Lewis
Johnston, Archibald
Johnston, C. D.
*Jones, C. A.
Jones, Evan F.
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Jones, I. O.
Jones, James C.
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Jones, William S.
Joseph, Eli
Joseph, Maurice
*Joyner, S. J.

*Karminski, Victor E.
Keefe, J. S.

Keeney, R. M.
*Keleher, F. B.
Keller, A. T.
Keller, Carl Tilden
*Kelley, G. L.
*Kelly, Joseph H., Jr.
Kennedy, Harry
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*Kennedy, Joseph W.
Kennedy, Julian
Kennedy, T. W.
*Kennedy, W. H.
Kenney, E. F.
*Kent, C. H.
Ker, Severn P.
Kernan, F. K.
*Kilgallen, M. H.
*Kilner, R. H.
Kimball, G. C.
King, John M.
*Kinsel, T. F.
*Kirkpatrick, H. B.
Kiroock, Howard R.
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*Klauer, W. H.
*Klein, L. C.
*Kling, F. E.
Klugh, B. G.
*Knecht, Marcel
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*Knott, Henderson W.
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Knox, L. L.
Konold, George F.
*Konold, M. J.
*Korndorf, L. H.
Kranz, W. G.
*Kreutzberg, Edgar C.
*Krieg, Charles
Krise, Raymond W.
Kruesi, Paul J.
Kuker, S.
*Kyle, W. T.

*Laing, Alfred I.
Lambert, John
Lamont, R. P.
Lanahan, Frank J.
*Langdon, Amon W.
*Langdon, William G.
Langenbach, Ed.
Larkin, J. K.
Larsson, C. G. Emil
Laughlin, Alex.
Laughlin, Alex., Jr.
Lavino, E. G.
*Lavino, E. M.
*Le Boutillier, Geo.
*Lee, W. J.
*Lee, H.
Leech, Malcolm W.
Leet, Geo. K.
Lehman, Albert C.
Lehman, I. F.
Lemoine, L. R.
*Lenhart, C. E.
*Lewis, D.
*Lewis, David
Lewis, H. E.
Lewis, R. A.
Lewis, W. H.
Lilly, Eugene Guy
*Lilly, Joseph T.
*Lincoln, L. P.
*Lindemuth, L. B.
Lines, F. F.
Lippincott, James
*Lissberger, B.
Little, Theodore W.
Llewellyn, F. T.
Llewellyn, Paul
Lloyd, J. F.
Locke, Wilbur S.
Logan, John W.
*Logan, Spencer
Lomax, H. A.
Loomis, O. W.
*Loose, Robert
*Loughman, E. D.
*Love, John
*Love, John H.
Lovejoy, Frederick B.
Low, C. H.
Lozier, Charles E.
Lukens, W. W.
*Lundberg, Charles
*Lundie, John
Lusk, Rollin W.
Lustenberger, L. C.
*Lynch, E. C.
*Lynch, Warren J.
*Lynn, Thomas H.
*Lyon, C. W.

*MacArthur, Donald
MacCleary, W. M.
*MacDonald, A. E.
MacDonald, D. C.
MacIlvaine, F. J.
*MacLean, William
*MacLean, William, Jr.
MacMurray, James E.
McAlarney, J. H.
McAteer, H. W.
McCaffrey, Thomas
McCauley, J. E.
McCleary, E. T.
McCleary, James T.
McCloy, John H.
McConnell, John
McCook, Willis F.
*McCracken, F. T.
*McCunn, J. M.
*McDonald, Donald
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*McDonnell, E. J.
McElhany, C. B.
*McElwain, John
*McFarland, J. K.
McFate, William M.
McGee, Harry L.
*McGraw, John B.
McGregor, Robert
McIlvain, Edward M.
McIntire, C. V.
*McIntyre, W. W.
McKay, Richard V.
McKee, Arthur G.
McKelvy, E. A.
McKenna, Roy C.
*McKinnon, Ross
McLauchlan, J. C.
McMahon, R. E.
McMahon, W. C.
McMillen, A. K.
*McNally, E. H.
*McVey, G. K.
*Maben, A. J.
*Mace, A. W.
*Mace, R. E.
Mackall, Paul
Maclean, M. R.
Maeder, C. E.
*Maguire, G. M.
*Mann, Ramsford V.
Manning, William E.
Mannweiler, E.
*Mansfield, Edwin
*Manville, T. F.
Marble, A. B.
*Marchand, Edgar
Marchant, C. R.
Mark, Clarence
*Markowitz, A. Lincoln
Marquard, F. F.
*Marsching, John H.
*Marseilles, W. P.
Marshall, C. D.
Marshall, C. S.
*Marshall, D. J.
Marshall, E. E.
*Mason, Willis H.
Mather, Amasa Stone
Mather, Samuel
Mather, S. L.
Mather, William G.
Mathews, John A.
Mathias, David R.
Mathias, Thomas H.
*Mayer, Jacob
*Mayers, J. A.
*Meehan, J. L.

Meissner, C. A.
*Meissner, C. E.
*Meissner, C. R.
*Meissner, H. G.
*Mereen, Arno
*Merrill, Chas. E.
Merriman, D. A.
*Merriman, W. G.
Mesta, George
Metcalf, Morris
*Meyer, A. L.
Meyers, F.
Michaels, Joseph
*Michel, R. H.
Michell, F. A.
*Middleton, Merle
*Millar, W. G. A.
Miller, C. L.
Miller, C. R.
*Miller, Dwight D.
Miller, J. C.
*Miller, Ward
Millhouse, William E.
Mills, Edwin S.
Mills, James R.
*Mitchell, A. S.
*Mitchell, W. P.
Mix, M. W.
Moffett, C. A.
Mogan, C. J.
Mohr, J. A.
Moon, George C.
*Moon, R. F.
Moore, H. G.
Moore, J. Turner
*Moore, M. M.
Moore, Philip W.
*Moran, E. F.
Moran, Frank
*Moran, J. H.
Moreland, A. McC.
Moreland, W. C.
Morgan, Paul B.
*Morgan, R. J.
Morgan, W. H.
Morris, A. F.
Morris, G. B.
*Morris, Reed
Morris, William J.
*Morrow, Alan D.
Morse, A. C.
*Morse, E. O.
*Morton, W. H.
*Moskowitz, Henry
Moss, J. B.
Muchnic, Charles M.
*Mueller, O. W.
*Muench, Louis
*Mundle, A. C.
*Murfey, S. L.
*Murphy, Deane
*Murray, J. B.
*Muse, C. A.
*Myers, William J.

Nagle, L. F.
Nash, Albert L.
Near, W. W.
Neeland, M. A.
*Negri, Giovanni
*Neubert, J. V.
Newcomb, C. H.
Newsom, H. H.
Newton, P. A.
*Nicholas, John P.
Nichols, J. A.
*Nicholsen, C. B.
Nicoll, Benjamin
Niedringhaus, Geo. W.
*Niedringhaus, H. F.
*Nields, Benjamin, Jr.
Niemann, C. F.
Norris, F. E.
*Norton, S. S.

*O'Brien, Morgan J., Jr.
Ogden, F. A.
*Ogden, George D.
*Olthoff, W. H.
*Olyphant, J.
*O'Reilly, J. B.
*Overholt, A. C.

*Page, Francis S.
*Page, J. J.
*Page, Rufus W.
Palmer, William P.
Pargny, E. W.
Parker, Edward L.
*Parker, J. A.
Parker, J. H.
Parsons, A. C.
*Partridge, J. B.
*Pease, J. D.
Peck, C. J.
*Peck, W. A.
Peckitt, Leonard
Peffer, George W.
Peirce, E. H.
Pendleton, Joseph S.
*Penhale, Clayton
Penton, John A.
Perkins, George W.
Perkins, H. F.
Perry, J. E.
Perry, J. Lester
Perry, W. F.
Pessano, Antonio C.
Peters, E. V.
Peters, Richard, Jr.
Petinot, N. G.
Pfeiff, L.
*Pfitsch, Charles G. A.
Pflager, Harry
*Phelps, J. H.
*Phelps, W. G.
*Phillips, F. Rees
*Phillips, John J. H.
Phillips, W. Vernon
*Picinich, A. D.
Pierce, Ewen C.
Pike, Charles W.
Pilling, G. P.
*Pilling, J. R.
Pilling, W. S.
*Piper, O. C.
Plummer, James
Pond, C. P.
Pope, Henry F.
*Poppenhausen, C. H.
*Post, Robert C.
Pratt, H. A.
Pratt, R. H.
Pratt, Theodore
Preston, Veryl
*Pugh, Stacy
*Purnell, Frank

Quinn, C. K.

Rachals, Walter
Radford, Robert
*Raffenberg, I. C.
Rainey, Roy A.
*Raleigh, Charles J.
Ramey, George W.
*Ramsbottom, David
Ramsburg, C. J.
Rand, Charles F.
Rathbone, R. L.
Rawstorne, C. D.
Rebman, Samuel
Reed, William I.
Reese, P. P.
Reeves, Samuel J.
*Regan, J. B.
*Regan, J. B., Jr.
Reilly, E. J.
Reilly, W. C.
Replogle, J. Leonard
Reynders, J. V. W.
Rhodes, C. H.
*Rianhard, T. M.
*Rice, E. W.
Rice, Richard H.
Rice, W. C.
Richards, F. B.
Richards, Joseph W.
*Richardson, H. C.
Riddle, L. E.
Rider, J. B.
Ridgway, William H.
*Riley, J. Joseph
*Roberts, Arthur
Roberts, W. F.
Robertson, Wm. F.

Robinson, C. S.
*Robinson, Dwight
*Robinson, E. S.
*Robinson, Edgar S.
Robinson, Theo. W.
*Robirds, E. E.
*Rodermond, R. B.
Roesch, J. A.
Rogers, William A.
Rose, George E.
Ross, L. P.
*Rotthaus, Julius
*Rowland, T F.
Rownd, H. L.
Ruiloba, J. A.
Rumney, John G.
*Rumney, Mason P.
Rumsey, S. S.
Runyon, Walter C., Jr.
Rushmore, David B.
*Russell, G. W.
*Russell, T. D.
Rust, E. M.
Rust, H. B.
Rust, S. Murray.
*Ryan, Allan A.
Ryan, F. J.
Ryerson, Donald M.
Ryerson, Joseph T.
Rys, C. F. W.

*Sage, R. V.
Samuel, Frank
Samuels, R. D.
*Sanborn, V. G.
Satler, Charles E.
Sattley, E. C.
*Saumening, H. M.
Sauveur, Albert
Savage, H. D.
Sawhill, E. P.
*Schaumberg, Otto
*Schiff, Isaac
Schiller, William B.
*Schmidlapp, Carl J.
*Schoch, Henry K.
*Schonley, H. S.
Schonthal, D. C.
*Schroeder, A.
*Schultz, L. C.
*Schuyler, W. M.
Schwab, Charles M.
*Schwab, J. E.
Schwartz, Louis
Scott, G. C.
*Seaberg, O. W.
*Seip, E. G.
*Sembower, G. K.
*Sewell, Oswald
Shants, G. T.
*Sharkey, James L.
*Sharp, Earnest
Sheridan, R. J.
*Sherwin, John
Shick, H. R.
Shimer, George S.
*Shimer, George S., Jr.
Shimer, W. R.
*Shinkle, W. B.
Shiras, MacGilvray
*Sholl, Edward P.
Short, G. W.
*Shotwell, Thomas C.
*Shriver, Harry T.
Sias, J. M.
*Sicard, Charles Louis
Siddall, Samuel
Siebert, W. P., Jr.
Sim, James
Simonds, A. T.
*Sinclair, D. G. C.
Sinn, F. P.
*Sinnott, W. C.
Sivyer, F. L.
Skiles, R. C.
*Skinner, Robert A.
*Slee, F. C.
Slick, Edwin E.
Slick, Frank F.
Sloan, Burrows
*Sloane, A. P.
*Sloane, Parker
*Sloane, W. D.
Slocum, F. S.
Smart, George
*Smart, H.
*Smith, C. A.
Smith, C. C.
Smith, Floyd K.
Smith, F. O.
Smith, James W.
*Smith, Pemberton
*Smith, W. W.
Snyder, H. S.
Snyder, W. P.
*Somme, Georges
*Sordes, J. F.
Souder, Harrison
Spackman, H. B.
Sparhawk, Edward M.
*Spear, L. Y.
*Spencer, S. N.
*Spilsbury, E. G.
Spilsbury, H. G.
Sproull, E. T.
*Staehle, A. M.
Stanford, George I.
Stansfield, Alfred
*Stapleton, L. D.
Stark, C. J.
St. Clair, Frank G.
Stearns, Edward B.
Stebbins, H. S.
Steel, Charles C.
Steif, Erwin A.
*Stephen, Harry M.
Stephenson, B. S.
Stephenson, J. I.
Stephenson, S. E.
Stevens, Charles G.
*Stevens, C. N.
Stevenson, A. A.
*Stewart, C. C.
Stewart, Hamilton
Stewart, Peter
Stewart, Scott
*Stillman, Albert R.
Stillman, J. S.
Stoddard, H. G.
*Stone, A. W.
Stone, E. E.
Stoughton, Bradley
*Stratton, S. W.
Stratton, W. H.
*Stroock, M. J.
Sturtevant, Paul
Sullivan, G. M.
Sullivan, George R.
Sullivan, W. J.
*Summer, S. N.
Summers, Harry W.
Sutphen, Henry R.
*Sutton, C. K.
Swann, Theodore
Sweeny, M. J.
*Sweet, W. A.
*Sweezy, Everett B.
Sykes, Wilfred

*Tackaberry, F. H.
*Taylor, Fred H.
Taylor, Knox
Taylor, T. H.
Taylor, Wade A.
Taylor, W. H.
Tener, Robert W.
Thayer, Rodney
*Thayer, V. R.
Thomas, A. J.
*Thomas, C. E.
Thomas, E. P.
Thomas, George, 3rd
*Thomas, Isaac B.
Thomas, L. E.
Thomas, T. E.
Thomas, W. A.
Thomas, W. J.
Thompson, A. W.
*Thompson, B. T.
*Thompson, Edward
*Thompson, H. L.
*Thomson, L. S.
*Thomson, W. P.
Thorp, George G.
*Thurston, L. S.
Tickner, Frank W.

*Tierney, John
Timmins, George
Tod, Fred
Todd, W. B.
*Topp, H. F.
Topping, John A.
Towne, Thomas
Townsend, H. E.
Townsend, J. F.
*Townsend, Richard
Trabold, Frank W.
*Treharne, E. B.
*Tripp, Roswell
*Troutman, W. E.
Tutein, E. Arthur

Unger, J. S.
Uphouse, H. G.
*Uterhart, Henry A.
Utley, S. W.

Valentine, S. G.
*Van Fleet, M. V.
*Van Gunten, Charles
Van Schaick, A. P.
*Veil, George S.
*Velte, R. C.
Vincent, Joseph E.
Vogel, Felix A.
Vogt, A. W.
Vom Baur, C. H.
Vosmer, W. F.
Vought, C. S.

Waddell, Jacob D.
Wadsworth, J. E.
Wagner, C. S.
*Wahlberg, Axel
Wales, Quincy W.
Walker, C. J.
Walker, Elbridge
Walker, John E.
Walker, W. R.
Wallingford, B. A.
*Walsh, Chas. E.
Walters, F. W.
*Walton, H. G.
*Wantz, Pierre
*Ward, J. Coleman
Ward, James H.
Wardwell, H. F.
*Waring, S. E.
Warren, W. H.
Waterhouse, G. B.
Waterman, F. W.
Watson, J. J.
Watson, W. E.
Wayland-Smith, R.
Webb, Albert R.
Webb, Francis J.
*Wegener, E. W.
*Weidlein, Luther B.
Weiss, J. G.
Wellman, S. T.
Wendell, Carl A.
*Wetzel, John E.
Weymouth, F. A.
*Whaley, A. R.
Wharton, Clifton, Jr.
Wharton, O. H.
Wheeler, Seymour
*White, Arthur
White, H. S.
*White, Prentice
*Whitney, R. H.
Whittemore, E. L.
Whyte, George S.
*Wild, E. M.
Wiley, Brent
*Willard, L. L.
Wille, Fred
Williams, Charles H.
Williams, H. D.
Williams, Louis W.
*Williams, R. B.
Wilson, Herbert M.
*Wilson, J. G.
*Wilson, J. P.
Wilson, L. B.
Wilson, P. F.
Wilson, Willard
*Wilson, Wm. C.
Winkler, L. H.
*Winne, Edward
*Winne, H. A.
*Wirth, Andrew
Witherbee, W. C.
Witherow, W. P.
*Witman, Walter F.
Wolfe, W. Lloyd
Wolhaupter, Benjamin
*Wolle, Lewis
*Wonham, F S.
Wood, A. D.
Wood, Charles L.
Wood, R. G.
Wood, Walter
Woodard, L. A.
Woods, John E.
Woods, L. G.
*Woodward, S.
Wooldridge, W. J.
*Worden, B. L.
*Worden, E. P.
Worth, E. H.
*Worth, W. A.
Worth, W. P.
Worton, Samuel G.
*Wright, C. E.
Wright, Philip E.
Wright, S. D.
*Wyman, Edward E.

Yates, Harry
Yeates, F. C.
Young, A. G.
Young, I. F.
*Young, O. D.

Zehnder, C. H.
Zehnder, E. M.
*Zeller, H. P.

PARTICIPANTS—OCTOBER MEETING

His Majesty, King of the Belgians, and His Suite.

His Majesty, Albert, King of the Belgians
H. R. H., Prince Leopold, Duke of Brabant
H. R. H., Prince Reginald de Croy
Baron E. de Cartier de Marchienne, The Belgian Ambassador
Lieutenant-General Baron Jacques
Colonel Thielkens
Colonel Le Tellier
Major of Artillery, Comte Guy d'Oultremont
Major-General William M. Wright
Rear Admiral Andrew T. Long
Max Leo Girard
Charles Graux
Lieutenant Baron Goffinet
Lieutenant-Colonel Nolf
Colonel Patterson
Major Hoffman
William Nye
G. Cornell Tarler

Abbe, A. N.
Abbott, F. E.
Abbott, W. H.
*Adams, D. C.
*Adams, Frank
Adams, Louis W.
*Aertsen, Guilliaem
Affleck, B F.
Agnew, J. C.
Agnew, John D.
Ahlbrandt, G. F.
Akin, Thomas R.
Alder, T. P.
Alderdice, George F.
*Allan, Frederick W.
Allen, James P.
Alley, James C.
Allyn, Alfred W.
Altemus, C. L.
Amaden, E. A.
*Amis, F. W. T.
Anderson, H. A.
Anderson, Nils
Andrews, Colonel
Andrews, J. I.
Angerer, Victor
*Anthony, George A.
*Apperson, J. S.
*Armsby, George
Armstrong, V. C.
Assmann, F. A.
*Atkinson, L. H.
*Austin, W. F.
Baackes, Frank
*Baackes, Frank, Jr.
*Badger, H. R.
*Bailey, A. M.
Baily, R. M.
Baily, T. F.
*Baird, Chester R.
Baird, Frank B.
Baker, E. D.
Baldwin, C. H.
*Baldwin, George J.
Baldwin, H. G.
Baldwin, L. S.
Baldwin, R. L.
Balkwill, George W.
*Balliett, B. J.
Bannister, J. C.
*Barber, E. J.
*Barbour, James W.
*Barby, F. A.
*Barker, Alfred K.
*Barnum, J. P.
Barr, C. J.
*Barr, J. C.
*Barrett, Guy
Barrows, W. A.
*Barrows, W. A., 3rd
*Bateman, James G.
*Bateman, W. H. S.
*Batteiger, R. L.
Battelle, Gordon
*Baylies, F. N.
*Beal, J. P.
Beale, A. H.
Beale, Harry S.
Beaumont, George H.
Becker, J.
Beegle, F. N.
*Beegle, N. G.
Bell, E. E.
Bell, C. H.
*Bell, Walter E.
Belsterling, Charles S.
*Bennet, D. R.
*Bennett, C. F.
Bennett, C. W.
Bent, Quincy
Berger, Charles
Bergquist, J. G.
*Best, Leigh
Bigelow, F. A.
Biggert, C. F.
Bigler, F. S.
Bindley, John
*Bingaman, R. W.
Bischoff, W. H.
Bixby, A. S.
*Blocher, J. R.
Block, E. J.
Block, L. E.
Blowers, William B.
Bonner, James B.
*Bonner, Leonard A.
*Booth, Thomas H.
*Booth, T. T.
Bothwell, W. J.

Bourne, Henry K.
Boutwell, Roland H.
Boutwell, Roswell M.
*Bower, W. C.
Boyd, P. M.
*Braden, U. S.
Bradley, Carl D.
Bradley, W. J.
Braid, Arthur F.
*Brandler, C. F.
*Briggs, Carl R.
*Brinkerhoff, W. J.
Brion, A. E.
*Brion, Lester
*Brodhead, F. M.
*Brokenshire, Earl L.
Brooke, Robert E.
Brooks, J. J., Jr.
*Brosseau, A. J.
Brown, Alexander C.
*Brown, Archer H.
Brown, Frank L.
*Brown. George W.
*Brown, H. B.
Brown, Lowell H.
*Brown, Shellman B.
Browne, DeCourcy
Bruce, R. A.
*Brudi, W. H.
Brunke, F. C.
Buck, C. A.
Buck, D. M.
*Buck, J. T.
Buckley, S. S.
*Buckman, H. P.
Budd, R. B.
*Budlong, M. G.
Buffington, E. J.
*Bugler, F. H.
Bull, R. A.
Burden, James A.
Burdick, Julian
*Burgess, G. K.
Burton, Carroll
Bush, D. Fairfax
Bush, S. P.
Butler, Gilbert
Butler, Joseph G., Jr.

Campbell, James A.
Campbell, L. J.
Cantley, C. L.
*Carey, James A.
Carney, F. D.
*Carpenter, C. W.
*Carpenter, W. T. C.
*Carrier, S. C.
*Carroll, Elbert H.
Carroll, W. A.
Carruthers, J. G.
Carse, Henry R.
Carse, John B.
*Carter, G. O.
Champion, D. J.
*Chapin, James C.
Chapman, Niles
Charls, G. H.
*Charter, I. R.
*Childs, E.
*Childs, W. H.
Christ, E. W.
Christian, A. W.
Church, E. S.
*Church, W. D.
Clark, Eugene B.
Clark, F. E.
Clark, Ralph W.
Clarke, E. A. S.
Claypool, G. L.
Clement, Harold T.
*Clements, Bert
Clopper, H. G.
Close, Charles L.
Cluff, Charles C.
Clyde, W. G.
Coakley, J. A.
*Coey, John Smiley
Coey, Stewart C.
Coffin, William C.
Cohen, Fred W.
*Cohen, Theodore
*Coit, Griffith
Colby, Albert Ladd
Colladay, Frank H.
*Colling, A. F.
Collord, George L.
Comstedt, Josef F. A.
Connell, F.
Connors, George W.
Cook, H. H.
Cook, Howard H.
Coonley, Howard
*Cope, F. T.
*Copley, R. A.
Corbett, W. T.
Corey, A. A., Jr.
Cornelius, Henry R.
Cort, Stewart J.
*Cotter, Arundel
*Craig, James
*Craig, S. N.
*Craig, William
*Crane, W. E.
*Cranwell, Thomas G.
*Craven, J. C.
Crawford, E. R.
Crawford, George G.
*Crawford, H. C.
Creighton, L. E.
Crocker, George A., Jr.
*Crosby, F. B.
*Crowley, R.
Croxton, D. T.
*Cubbert, I. T.
Cummings, S. H.
*Curley, J. F.
Curtis, M. S.

Daft, Andrew C.
Dalton, H. G.
Dalton, William
Damerel, George
Danforth, Arthur E.
*Daniels, F. H.
Darlington, Thomas
*Darragh, A. D.
Davey, W. H.
Davis, Charles C.
*Davis, W. A.
Davison, J. V.
*Daw, F. W.
*Debevoise, Paul
*DeCamp, R. J.
DeLano, S. P.
*Denman, L. E.
Dennis, M. S.
Denton, I. H.
*Denyven, G. W.
Desmond, John F.
*Detmers, A. C.
*Detmers, Sidney
Dette, William
Deutsch, Lee
Devens, Richard
*Dewey, V. F.
*Dickey, Clyde E.
Dickey, W. C.
Dickson, W. B.
*Dieks, A. N.
*Digan, T. J.
Dilks, Lorenzo C.
Dillon, A. H.
*Dillon, A. S.
Dinkey, A. C.
*Disbrow, C. A.
*Dixon, A. Morris
*Dixon, John
Dodd, Alfred W.
*Dodge, F. E.
D'Olier, William L.
*Donaldson, W. G.
Donner, Joseph W.
Donner, Robert
Donner, W. H.
*Donovan, William F.
Dorman, A. D.
*Dorman, P. O.
Dougherty, J. W.
*Douglass, E. P.
*Dow, H. G.
*Dowden, A. G.
*Downey, E. Kelly
Drake, Fred R.
Duane, James
*Duncan, T. S.
Dunham, L. E.

*Edgerly, W. H.
Edwards, V. E.
*Eichenlaub, W. C.
Ellis, Frank I.
Ellis, J. M.
*Emmons, Thornton
Enck, W. B.
Endicott, George
Enlow, A. T.
Eppelsheimer, D.
Eschenbrenner, D. F.
Estep, H. C.
*Evans, Charles
*Evans, T. W.
Eynon, David L.
Eynon, D. L.

*Fagan, J. J. P.
*Farmer, Malcomb
Farrell, James A.
Farrell, John
Farrell, J. J.
*Fawcett, A. S.
Fehling, O. J.
*Feigelstock, William A.
*Feiser, M. L.
Fenton, C. M.
*Ferguson, Henry
Field, H. F.
Fields, H. E.
*Finch, J. H.
Fisher, Charles A.
Fitch, W. H.
Fitzgerald, J. E.
*Fitzgerald, J. J.
Fitzpatrick, F. F.
*Fletcher, F. F.
Fletcher, John F.
Floersheim, B.
Follet, Louis
Forbes, William A.
*Force, C. W.
*Forgey, J. E.
*Forker, J. N.
Forrest, J. D.
Forster, C. H.
*Foster, H. M.
*Foster, R. L.
Fowler, A. A.
Francis, Lewis W.
Fraser, Allan
*Fraser, George C.
Freeman, S. S.
*French, James
*Frew, W. E.
Freyn, H. J.
*Frick, C.
*Frick, Henry C.
Fries, J. Elias
*Froander, E. F.
*Frost, Frank R.
Fry, John A.
Fry, L. H.
Frye, J. K.
Fuller, F. A.
Furst, J. K.

*Gable, H. C.
*Gaffney, A. T.
*Gaffy, W.
*Galbraith, A. T.
Galvin, John E.
*Gardner, C. B.
Gary, Elbert H.
Geddis, Robert
*Geehr, Edward C.
Gellert, N. H.
*George, E. Howard
George, Jerome R.
Gerry, Roland
Gessler, Theodore A.
Gilbert, H. T.
*Gillespie, R. W.
*Gilmore, Thomas, Jr.
Glasgow, Walter H.
Glass, Alex.
Glass, John
Glenn, Thomas K.
*Gomber, William
Gordon, F. H.
Grace, Eugene G.
Graff, Everett D.
Graham, Charles J.
Gray, George H.
Green, J. B.
Green, W. M.
Gregg, W. W.
Gresham, W. B.
Griffin, J. B.
Griffith, D. M.
Grugan, Justice
Gruss, William J.
Guba, P. M.
Gulick, Henry
*Guttzeit, Charles

*Hackett, John
Hackett, S. E.
*Hall, H. M.
Hall, R. S.
Hamill, Lawrence
Hamilton, Alex. K.
*Hamilton, Fred D.
Hamilton, H. V.
Hamilton, J. W. H
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*Hammond, J. W.
Hansell, N. V.
*Harris, Charles
Harris, George E.
Harris, W. B.
*Harrison, Chas. C., Jr.
Harrison, E. W.
*Harrison, L. H.
Hart, G. A.
Hart, William F.
*Harvison, L. H.
Havemeyer, John F.
*Hawkes, A. W.
*Hayman, E. J.
*Hays, George L.
*Hays, George O.
*Hays, W. C.
*Hazen, W. E.
*Hazlewood, Stuart
Hearne, William W.
*Hemingway, W. C.
Hendricksen, J. J.
*Heneage, H. R.
Hickman, R. Baylor
Hickok, C. N.
Higgins, Dean
Hilands, J. P.
Hildrup, W. T., Jr.
Hird, Roy G.
Hobson, Robert
*Hodge, C. W.
Hoffer, Allen
*Hoffman, R. J.
Hoffman, W. L.
Holbrook, Percy
*Hollingsworth, W. T. P.
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Holloway, W. W.
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Holmes, George C.
*Holmood, Somers
*Horner, Vaughan
Horner, W. S.
Hotchkiss, C. W.
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Howe, Henry M.
Howell, A. C.
*Howell, Lardner
*Hoyt, Colgate
*Hoyt, Colgate, Jr.
Hoyt, Elton, 2nd
Hubbard, P. H.
Hudson, A. H.
Hudson, Banks
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*Hughes, Allan
Hughes, Edward E.
*Hughes, E. P.
Hughes, H. L.
Hughes, I. Lamont
*Hughes, J. H.
Hughes, John
Hughes, William H.
*Hulick, C. E.
Hulst, J.
Hume, J. E. N.
Hunter, John A.
*Hurlbert, E. G.
Hurlbert, William G.

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Hutchinson, O. N.

*Igoe, Andrew
*Igoe, James
*Igoe, Peter
Ingalls, R. I.
Ireland, James D.
*Isbester, G. C.
Isham, Phillips

James, Henry L.
Jameson, A. H.
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Jarecki, Alexander
*Jayne, D. W.
*Johnson, A. E.
*Johnson, F. E., Jr.
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*Johnson, Roe L.
*Johnson, T. M.
Johnston, Archibald
Johnston, C. T.
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*Kahil, A. A.
Kauffman, Walter L.
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*Kaufman, Joseph S.
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*Kellog, W. O.
Kellogg, M. W.
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*Kelly, J. F.
Kelly, M. B.
Kennedy, Dudley R.
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*Kennedy, J. W.
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*Kennedy, William H.
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Ker, Severn P.
Kernohan, R. B.
*Kerr, E. C.
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*Keyes, H. B.
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*King, S. Victor
King, Willis L.
*Kinsel, T. F.
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Knox, L. L.
Koch, C. S.
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*Konold, M. J.
Korndorff, L. H.
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Kuker, S.
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Lambert, John
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Larkin, Joseph K.
Lashar, W. B.
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Leck, Walter W.
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Leech, Malcolm W.
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Linton, Robert
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*Lissberger, M.
Little, Theodore W.
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Logan, John W.
Lomax, H. A.
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*Loughman, W. E.
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MacDonald, R. A.
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*Morris, W. T.
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Newsom, H. H.
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*Perkins, Walter G.
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*Perry, R. P.
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Petinot, Napoleon
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Rand, Charles F.
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*Rhodes, F. H.
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Romeyn, Radcliffe
Rose, G. E.
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*Ross, D. W.
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Runyon, Walter Clark
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Rys, C. F. W.

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*Schaumberg, Otto
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Schneider, A. A.
Schneider, Eugene
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*Schoonmacker, A.
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Scott, George C.
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*Sicard, Charles Louis
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Simonds, A. T.
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*Sloane, Wm. Douglas
Slocum, Frank S.
Smart, George
Smith, B. S.
Smith, F. K.
Smith, Frederick O.
*Smith, H. F.
Smith, H. Sanborn
*Smith, John Thomas
Smith, J. W.
*Smith, Montgomery
*Smith, W. C.
*Smith, W. H.
*Smith, W. W.
Snyder, H. S.
Soden, C. P.
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Spilsbury, H. G.
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*Stanley, E. O.
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*Steer, E. J.
Steif, Erwin A.
*Steiner, C. L.
*Sterrett, W. M.
*Steuer, Louis R.
Stevens, Charles G.
*Stevens, C. N.
Stevenson, A. A.
Stewart, Hamilton
*Stillman, A. L.
Stillman, J. S.
*Stitte, W. C.
*Stimpson, H. F.
*Stoll, H. E.
Stone, Charles F.
Stoughton, Bradley
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*Stroock, M. J.
*Sturgus, William B.
Sturtevant, Paul
Sullivan, Corliss E.
Sullivan, George M.
Sullivan, George R.
Sullivan, W. J.
*Swann, H. S.
Swann, Theodore
Swart, W. G.
Sweeney, M. J.
*Sweet, W. A.
*Sweet, William M.
Sykes, W.

*Taussig, W. M.
*Taylor, Fred H.
Taylor, Knox
*Taylor, S. P.
Taylor, T. H.
Taylor, Wade A.
Taylor, W. H.
Terry, Charles D.
*Thiess, Robert H.
*Thatcher, W. F.
Thomas, A. J.
*Thomas, C. E.
Thomas, C. S.
Thomas, E. P.
Thomas, George, 3rd
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Thomas, W. A.
Thompson, E. D.
Thompson, G. M.
*Thompson, J. I.
*Thompson, James M.
*Thomson, L. S.
*Thomson, W. P.
Timmins, George
*Timmons, C. A.
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Tod, Fred
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Topping, John A.
Topping, W. B.
Towne, Thomas
Trabold, Frank W.
Tracy, David E.
Trimble, H. N.

*Turnbull, Robert
*Tutein, D. A.
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Unger, J. S.
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*Usina, D. A.

*Valentine, E. A.
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*Van Swieten, R.
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*Vernon, W. M.
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*Vinnedge,, R. R.
Viot, H. R.
Vogel, Felix A.
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Vosmer, W. F.

Waddell, Jacob D.
Wagner, C. S.
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Walker, John
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*Walmsley, W. N.
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*Walters, L. D.
*Walters, P. N.
*Walton, H. G.
*Walton, W. P.
*Ward, Eliot
Ward, J. H.
Wardwell, H. F.
Warner, Joseph
*Warren, James
Waterhouse, G. B.
Watson, W. E.
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*Weiss, F. A.
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*Wells, Oscar
Wendell, Carl A.
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Wharton, O. H.
*Wheeler, John
Wheeler, Seymour
*White, Charles F.
*White, Charles S.
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*White, R. W.
*White, S.
*White, W F.
*Whitney, R. H.
Whittemore, E. L.
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Whyte, George S.
*Wight, S. B.
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Wilkinson, H. S.
Williams, Charles H.
Williams, H. D.
Williams, L. W.
Williams, Leonard W.
*Williams, Ralph B.
Wilson, L. B.
Wilson, Parker F.
Wilson, Willard
Witherow, W. P.
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*Worden, B. L.
*Work, Edgar W.
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Worth, E. H.
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Wright, William H.
Wuthenow, W.
*Wyatt, C. A.

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Yeates, F. C.
Young, Andrew G.
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